TITLE PAGE

INTRODUCTION TO SPACE NAVIGATION

TEXT 3, SECTION 1

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GENERAL MOTORS CORP.

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PREFACE

The SPACE NAVIGATION AND ORBITAL MECHANICS COURSE is divided into three volumes:

INTRODUCTION TO SPACE NAVIGATION

INTRODUCTION TO ORBITAL MECHANICS AND RENDEZVOUS TECHNIQUES

APPLIED ORBITAL MECHANICS

Each volume consists of one or more programed instruction texts. Each text contains a list of prerequisities and a list of objectives.

The prerequisites tell you what you should already know before you begin the first section of programed instruction material. If you cannot meet the prerequisites, you will find it very difficult to proceed through the text.

The objectives tell you what you will be able to do upon completion of the text, i. e., the objectives tell you what problems you'll be able to solve, what items you'll be able to define, etc. If you can satisfy the objectives without reading the text, proceed to the next text.

This text is yours to keep. You may want to write, sketch or underline in it. The more you participate, the more you will learn and the longer you will remember what you learn. Should you wish to review the text in a year or so, your notes would be quite valuable in refreshing your memory.

INTRODUCTION

This book contains the first section of Text 3 of Volume 1 of the SPACE NAVIGATION AND OBRITAL MECHANICS COURSE. Text 3 contains the following sections:

SECTION 1: PLOTTING THE LUNAR PATH ON A STAR CHART

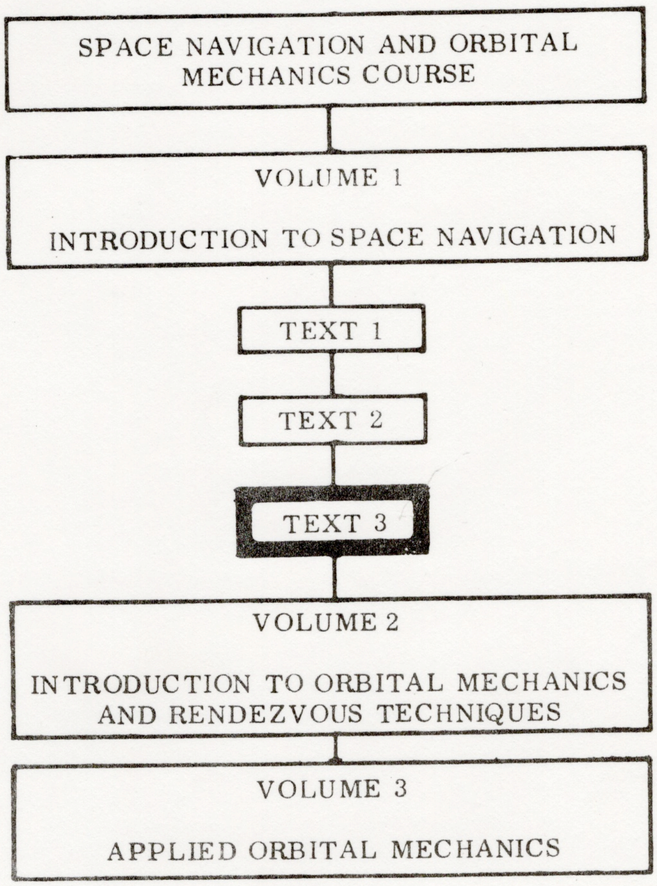
SECTION 2: PLOTTING SPACECRAFT PATHS ON A STAR CHART

SECTION 3: PLOTTING SPACECRAFT PATHS ON AN EARTH MAP

The second two sections are bound separately and have their own objectives and test.

Section 1 explains the periodic motions of the Moon and the lunar plane, then shows how the Moon's path can be plotted on a star chart, and how this path can be used to determine lunar phases and available navigation stars. Section 2 shows how to plot a spacecraft's path on a star chart, then demonstrates how to determine available navigation stars. Section 3 shows how to plot a spacecraft's path on an Earth map, how to determine which sections of Earth are in Sunlight for any given time, and how to correlate the spacecraft's path on a star chart with its path on an Earth map.

The drawing below shows how Text 3 fits into the SPACE NAVIGATION AND ORBITAL MECHANICS COURSE.



PREREQUISITES

Before starting this text, you should have successfully completed INTRODUCTION TO SPACE NAVIGATION TEXT 2.

OBJECTIVES

Upon completion of this section of Text 3, you will be able to do the following:

1. Given graphs showing i vs years and Ω vs years, sketch the approximate path of the Moon on a star chart for any year covered by the graphs.

2. Given an illustration of the lunar, equatorial, and ecliptic planes, identify the following:

   A. ascending lunar node
   B. descending lunar node
   C. Ω
   D. axis about which the lunar plane rotates

3. Given a lunar orbital path and the date of the ascending or descending node, determine the approximate dates of the other node and the maximum north or south declination.

4. Given a calibrated lunar orbital path on a star chart and the date of the ascending node, determine the approximate dates of the new and full moon.

5. Define the:
   A. orientation of the lunar plane
   B. direction and period of rotation of the lunar plane

DIRECTIONS FOR USING TEXT

The majority of frames in this text each have one or more questions. The answers to these questions always appear in the beginning of the following frame.

Basically, there are two types of questions used. The first is used with "lecture" frames; i.e., frames which present complete units of information or concepts. This type of question tests your comprehension of the material in that frame.

The other type of question is used with frames in which the information or concept is intentionally left incomplete. In these frames, the student is required to use whatever information he is given (either in the text of the frame or an illustration referenced from the frame) to answer the question. The answer to this question, then, completes the concept or unit of information presented in the frame.

INSTRUCTIONS

1) READ THE FRAME MATERIAL

2) ANSWER THE QUESTIONS IN THAT FRAME

3) CONFIRM YOUR ANSWERS AND REVIEW THE FRAME MATERIAL IF NECESSARY

4) REPEAT STEPS 1, 2, AND 3 UNTIL THE SECTION IS COMPLETED

5) ANSWER ALL REVIEW QUESTIONS

6) CONFIRM REVIEW QUESTION ANSWERS

7) REVIEW THE ITEMS YOU HAVE INCORRECTLY ANSWERED UNTIL YOU HAVE MASTERED THE MATERIAL IN THAT SECTION

SECTION 1

PLOTTING THE LUNAR PATH ON A STAR CHART

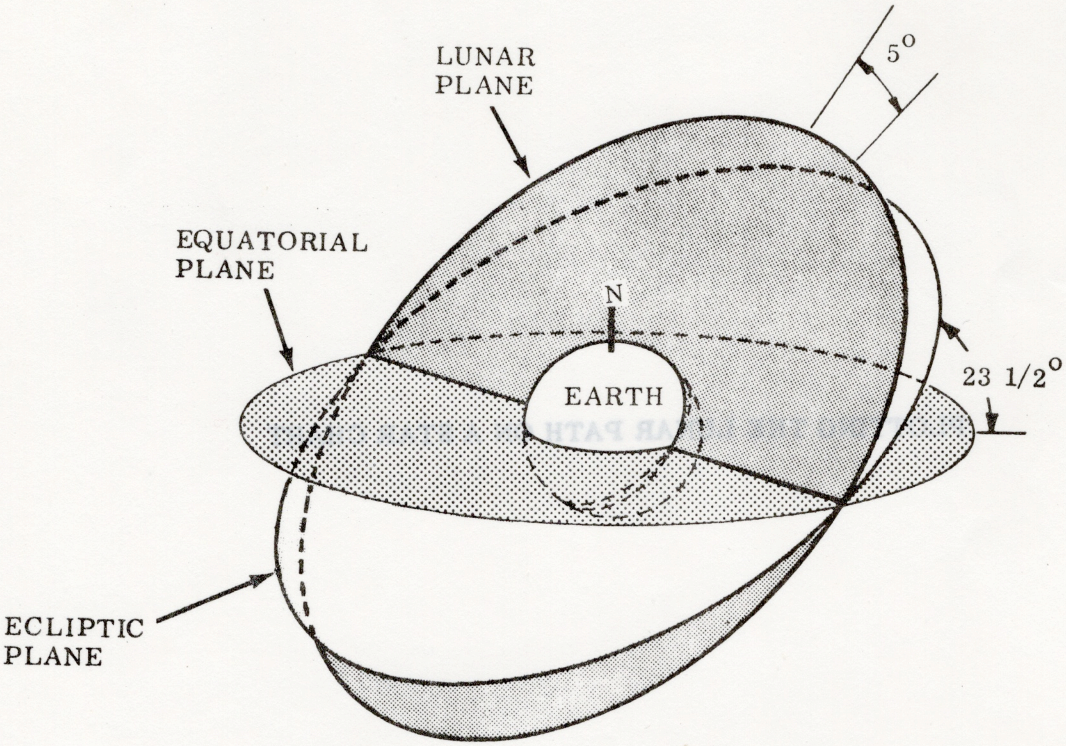


FIGURE 1-1.

As the title says, this section will be devoted to plotting the path of the Moon on a star chart. Before we can get into the actual plotting, however, we will have to spend some time explaining the motion of the lunar plane with respect to the equatorial and ecliptic planes. All three planes are shown in figure 1-1. Luckily, the ecliptic and equatorial planes are fixed with respect to each other, so the only motion we have to worry about is that of the lunar plane.

1. The line defined by the intersection of the ecliptic and equatorial planes points to a fixed spot on the celestial sphere. This spot has a right ascension of __________ ______________________ and is called the ______________________________ or the ______________________________.

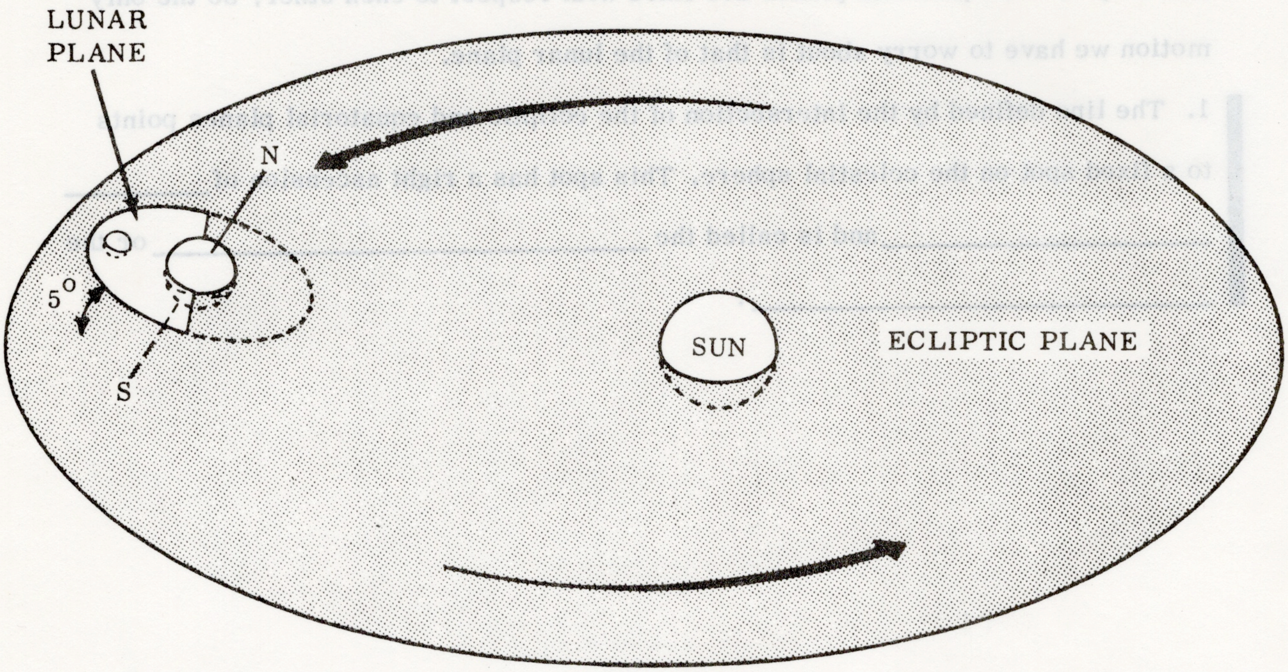


FIGURE 1-2.

1-2

<u>ANS-1</u>: 0 hours

first point of Aries

vernal equinox

Now let's break things up a little and take the planes two at a time rather than all together. First, we'll take the lunar and ecliptic planes and forget about the equatorial. As you can see from figure 1-2, these two planes intersect in much the same way as the equatorial and ecliptic planes do.

2. The lunar plane intersects the ecliptic plane at an angle of ______________.

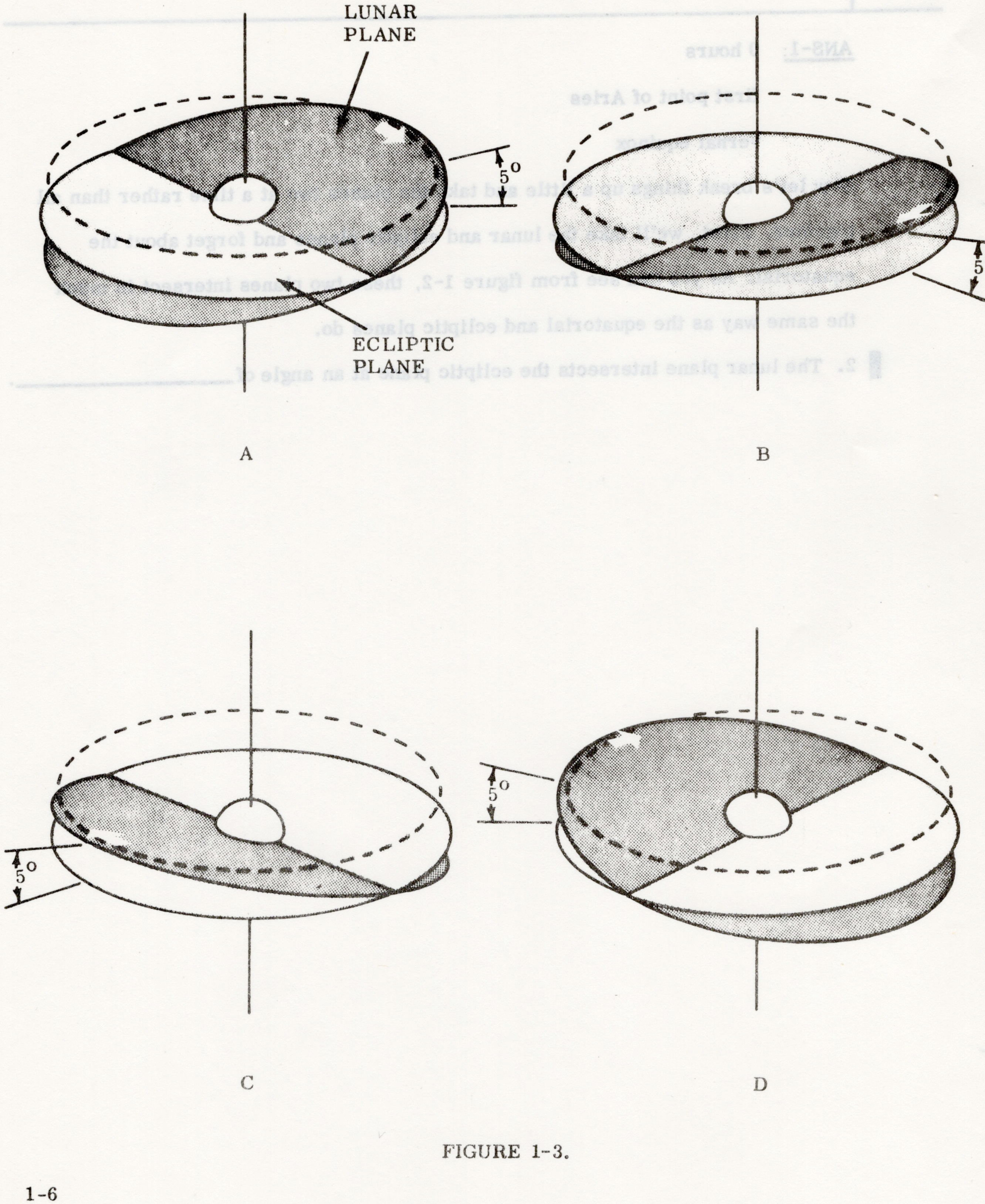


FIGURE 1-3.

1-3

ANS-2: 5^{o}

As we said, the lunar plane moves around. To be more specific, it rotates, as shown in figure 1-3.

3. The lunar plane rotates ______________ (CW/CCW) about an axis which appears to be ____.
(parallel to the ecliptic plane/perpendicular to the ecliptic plane/perpendicular to the lunar plane/perpendicular to the equatorial plane).

1-4

ANS-3: CW

perpendicular to the ecliptic plane

Notice the angle between the planes, however.

4. Even though the lunar plane rotates, the angle between the lunar and ecliptic planes ______________________________.

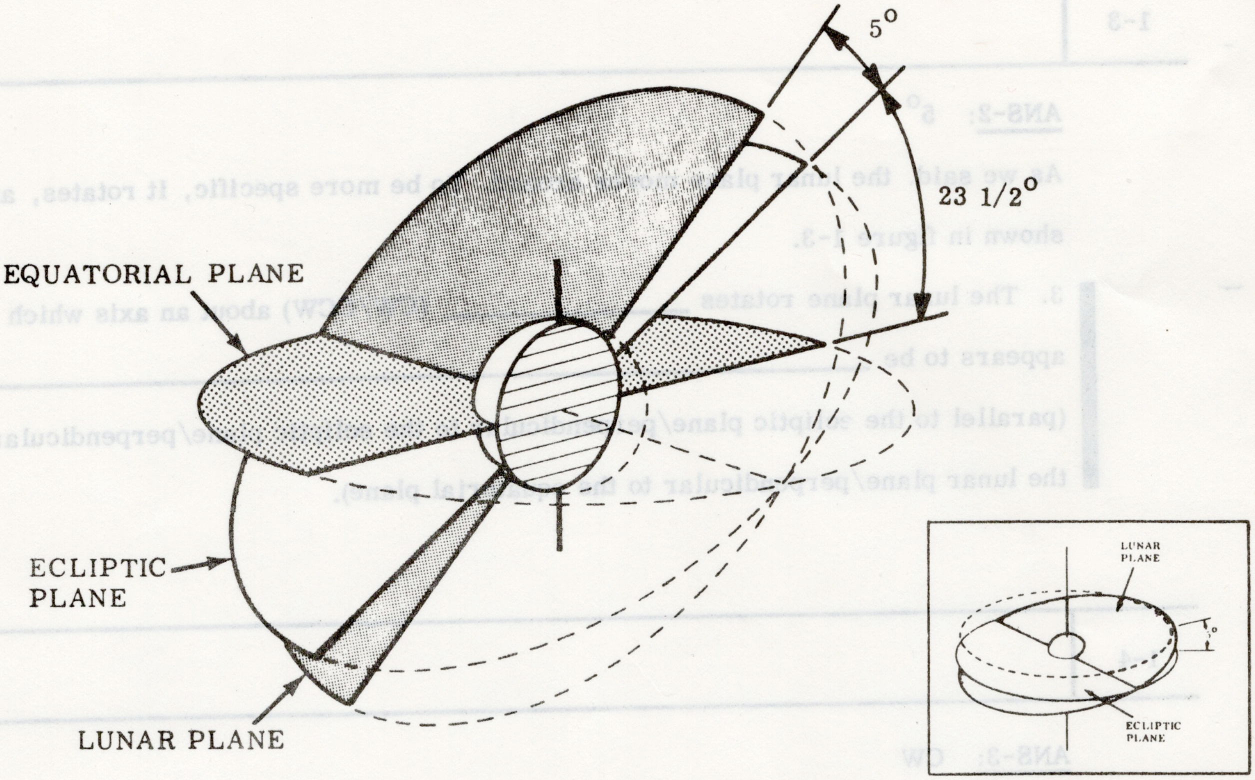


FIGURE 1-4.

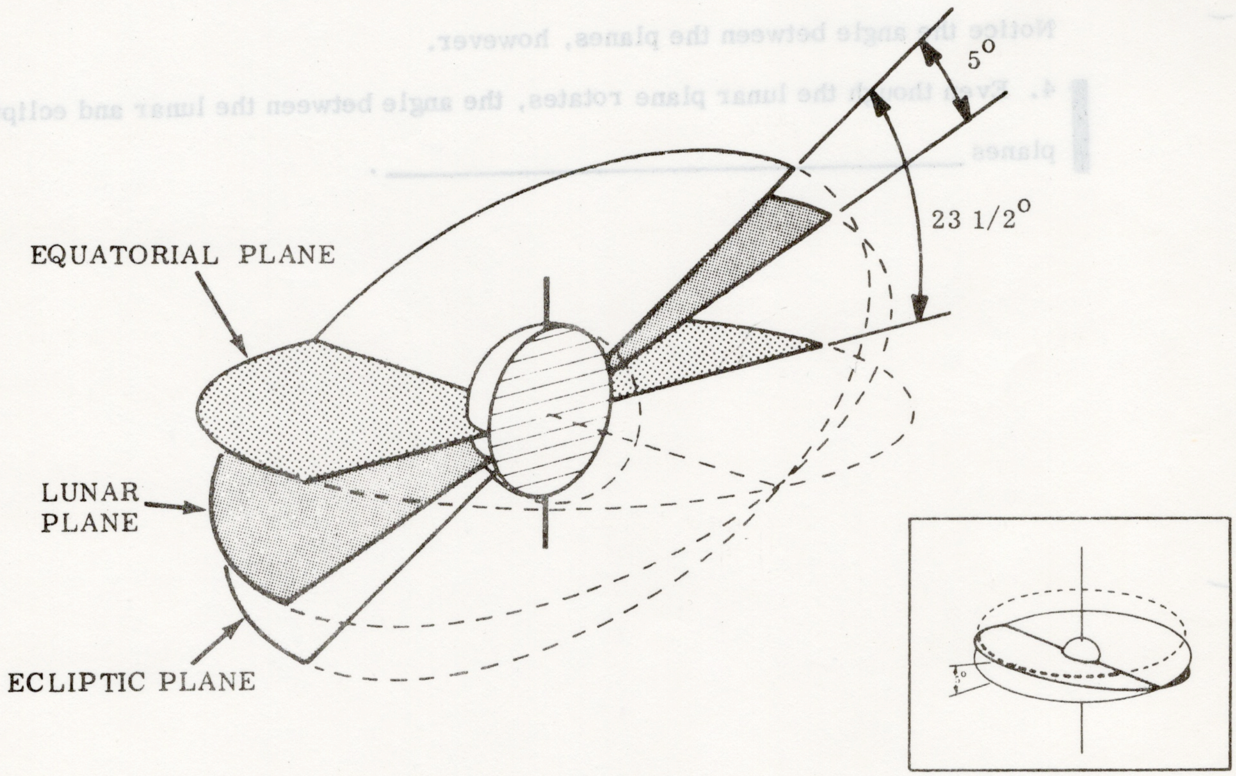


FIGURE 1-5.

1-5

ANS-4: remains constant

or

is always 5°

So, we have established that the lunar plane is always tilted 5° with respect to the ecliptic plane and rotates about an axis perpendicular to the ecliptic plane. But what has been happening with respect to the equatorial plane?

Actually, two things have been happening, and we will tackle each one separately. First, let's take a cross section of all three planes, as shown in figure 1-4. Notice particularly that this cross section is taken in a plane which passes through the center of the Earth and is perpendicular to the line of intersection between the ecliptic and equatorial planes.

5. The view in figure 1-4 corresponds to section A of figure 1-3. In this position, the lunar plane is tilted how many degrees with respect to the equatorial plane? ______

1-6

ANS-5: 28 $1/2^{\circ}$

As you can see, in the position shown in figure 1-4, the two angles are added. But now, take the position shown in figure 1-5. This position corresponds to section C of figure 1-3, after the lunar plane has rotated 180°.

6. The angle between the lunar plane and the equatorial plane is how many degrees in figure 1-5? ______________

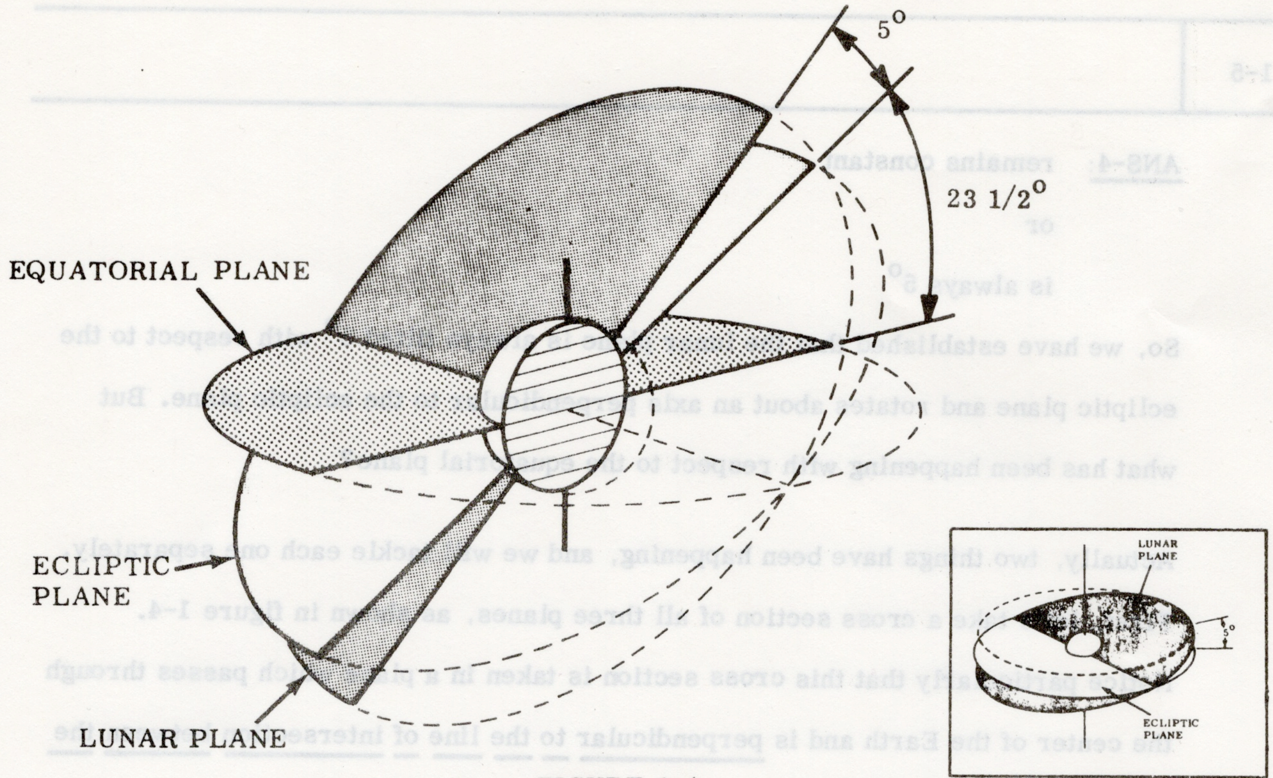


FIGURE 1-4.

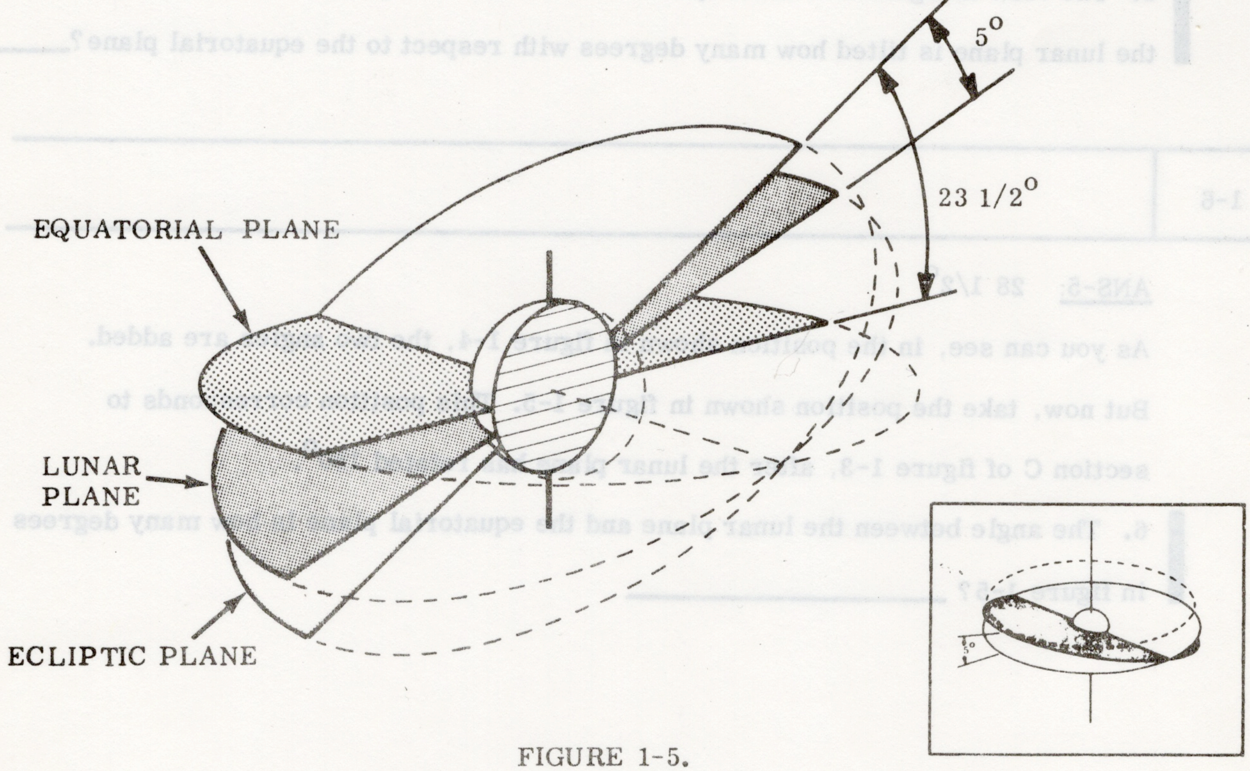


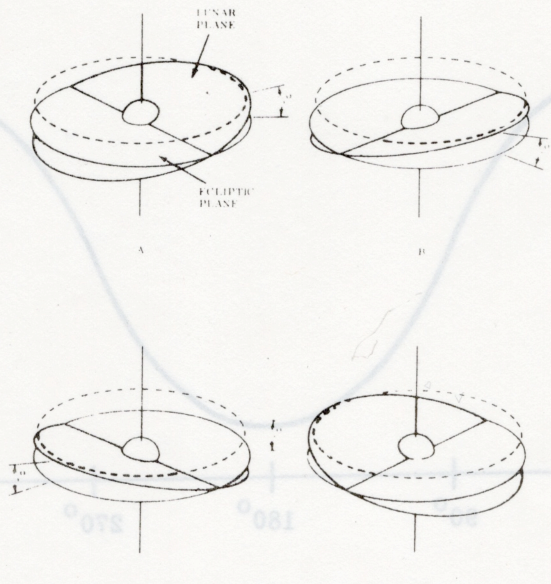
FIGURE 1-5.

<u>ANS-6:</u> 18 1/2°

After 180° of rotation, the lunar plane is positioned so that the 5° of lunar tilt is subtracted from the 23 1/2° between the equatorial and ecliptic planes.

Since the rotation from 0° to 180° is a continuous motion, the transition of the lunar plane's inclination from 28 1/2° to 18 1/2° must also be continuous. (Don't try to visualize this in terms of the planes shown in figure 1-1, yet: stick with our cross sectional view for the time being.)

7. Assuming the change in the lunar plane's inclination with respect to the equatorial to be continuous, what would you expect that inclination to be after 90° of rotation (Section B of figure 1-3, repeated below)?



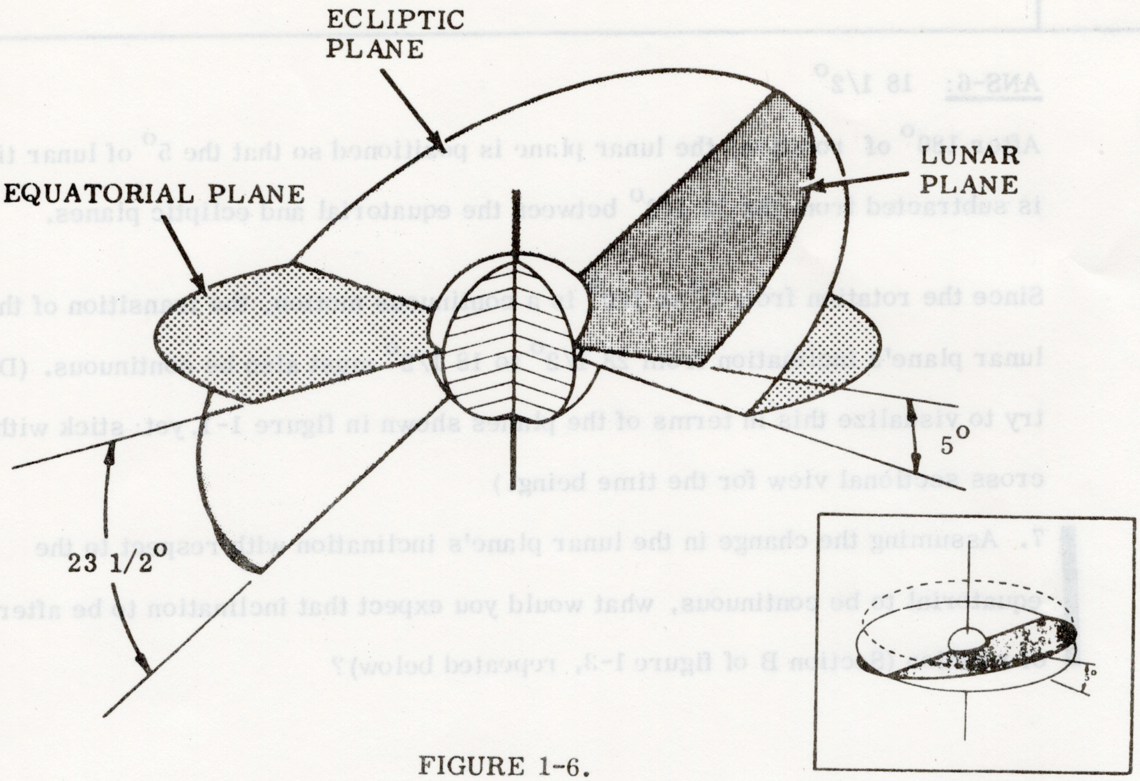


FIGURE 1-6.

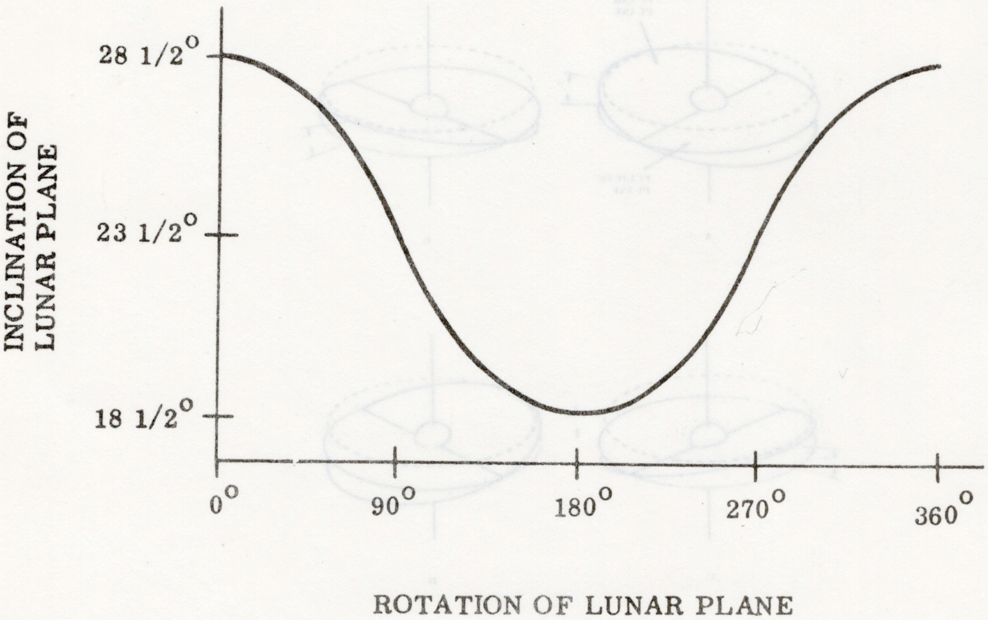


FIGURE 1-7.

1-8

ANS-7: $23\ 1/2^{\circ}$

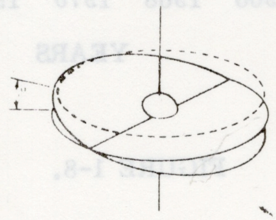
If you have any trouble seeing how the lunar plane can be inclined $23\ 1/2^{\circ}$ with respect to the equatorial plane and still be inclined 5° with respect to the ecliptic plane, take a look at figure 1-6. Notice that, even though the lunar and ecliptic planes are still inclined 5° with respect to each other, they are coincident in the plane of the cross section we have been using. That is, the plane in which our cross sections have been taken passes directly through the line of intersection of the lunar and ecliptic planes.

8. How much beyond the position shown in figure 1-6 would the lunar plane have to rotate before the lunar and ecliptic planes would again be coincident in the plane of our cross section? ______________________

1-9

ANS-8: 180°

This would, of course, correspond to section D of figure 1-3, repeated below.



From our cross-sectional point of view, then, the lunar plane literally see-saws up and down with respect to the equatorial plane as a result of the lunar plane's rotation. The results of one complete rotation of the lunar plane are shown in figure 1-7.

9. After 45° of rotation, the angle between the lunar and equatorial planes is approximately ______________________.

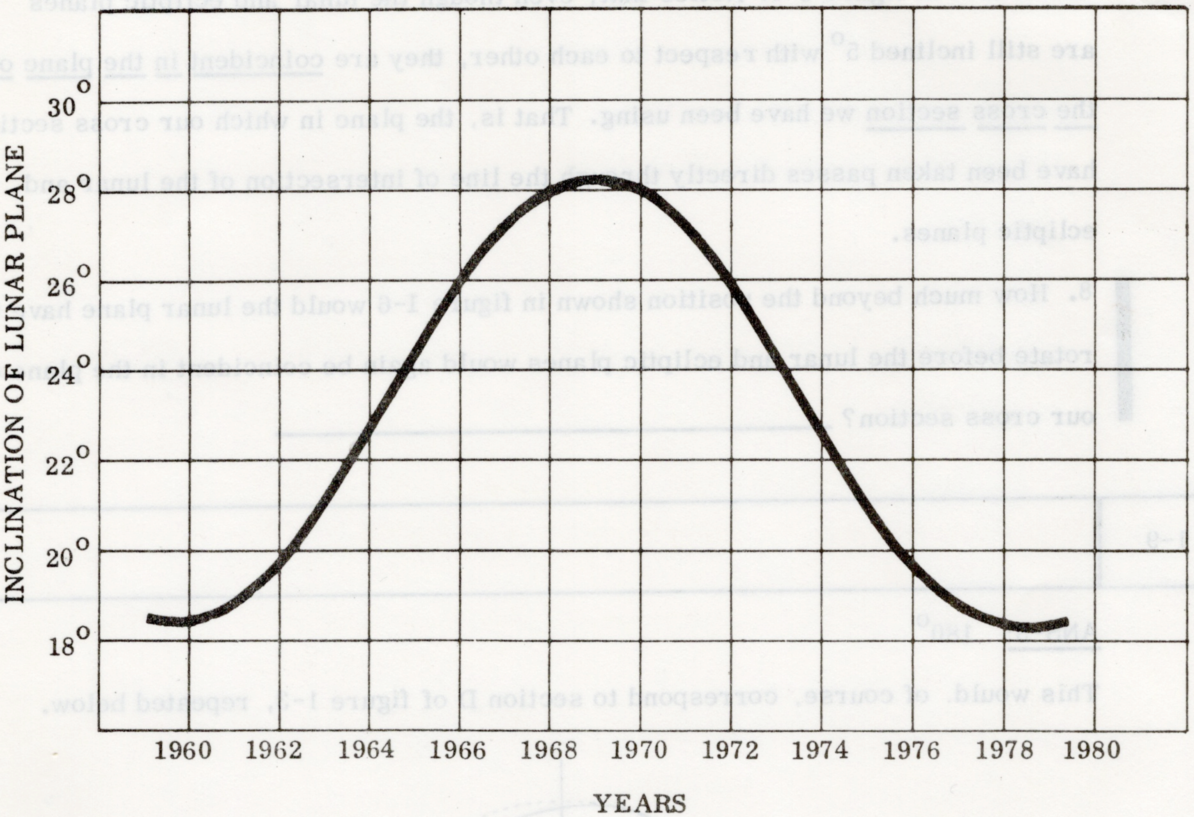

INCLINATION OF LUNAR PLANE
30°
28°
26°
24°
22°
20°
18°
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
YEARS

FIGURE 1-8.

1-10

ANS-9: 27°

The lunar plane completes one rotation every 18 1/2 years. The current cycle, from about 1960 to 1980, is shown in figure 1-8.

10. The maximum angle between the lunar and equatorial planes during the present cycle occurs in ________________.

1-11

ANS-10: 1969

As you know, the inclination of the ecliptic to the equatorial plane determines how far north in the sky the Sun goes.

11. Similarly, the inclination of the lunar plane to the equatorial plane determines how far north in the sky the ________________ goes.

1-12

ANS-11: Moon

The Sun, moving as it does along the ecliptic, reaches a maximum northern latitude of $23\ 1/2^{\circ}$ once each year. That is, once each year, the Sun appears to be directly overhead to an observer at $23\ 1/2^{\circ}$ north latitude.

12. During 1969, the Moon reaches a maximum northern latitude of ________.

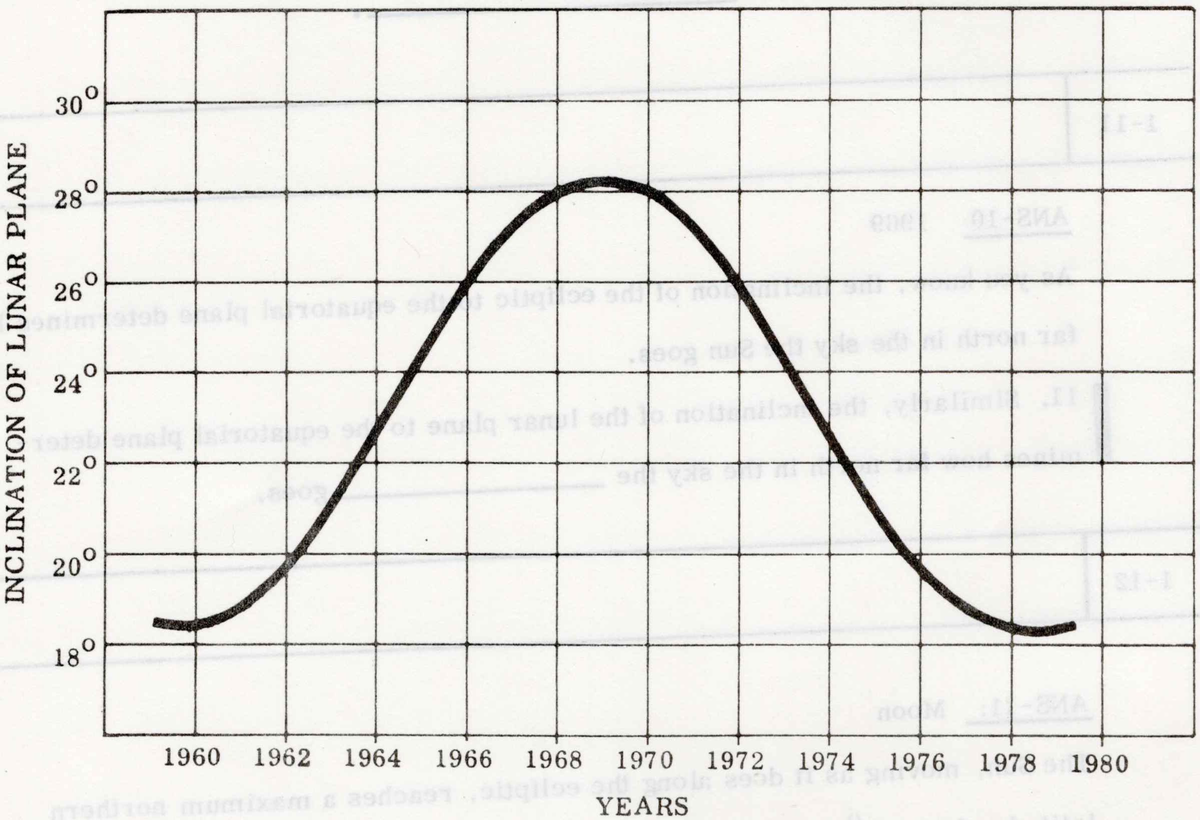

INCLINATION OF LUNAR PLANE
30°
28°
26°
24°
22°
20°
18°
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
YEARS

FIGURE 1-8.

ANS-12: 28 1/2°

All this means is that, during 1969, an observer at 28 1/2° north latitude passes through the lunar plane once each day. If we add two more facts, the economics of lunar inclination should become clear.

1. For a trip to the Moon, the most economical trajectory would result if the launch were made from a site directly in the lunar plane.

2. Cape Kennedy is located at approximately 28 1/2° north latitude.

13. The best year during the current cycle for a trip to the Moon would be ______________. The worst year would be ______________.

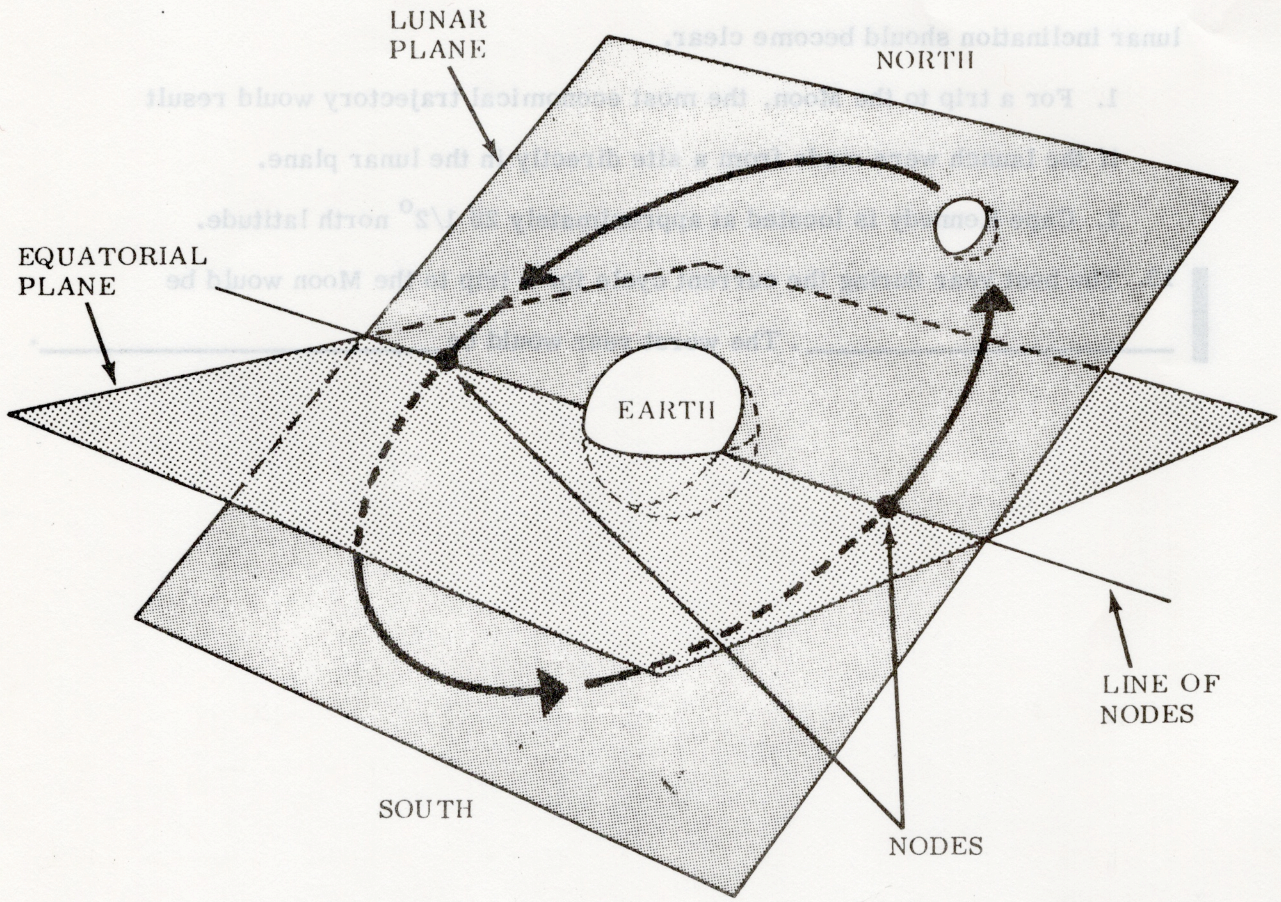

LUNAR
PLANE
NORTH
EQUATORIAL
PLANE
EARTH
LINE OF
NODES
SOUTH
NODES

FIGURE 1-9.

1-14

ANS-13: 1969

1978

1978 is the year in which the lunar plane is furthest from Cape Kennedy. So, we have found the first half of the answer to the question we posed back in frame 1-5. We have found that one result of the lunar plane's rotation is a constantly varying inclination of the lunar plane with respect to the equatorial plane. For the other half of the answer, we will have to introduce some new terms and review some old ones.

To start with, let's take a look at the equatorial and lunar planes as shown in figure 1-9. The points at which the Moon passes through the equatorial plane are called nodes.

14. You would expect the node at which the Moon goes through the equatorial plane from south to north to be called the ______________ (ascending/descending) node.

1-15

ANS-14: ascending

Similarly, the node which marks the Moon's passage through the equatorial plane going from north to south is called the descending node.

Logically enough, if we draw a line connecting these nodes, it is called a line of nodes.

15. Stated another way, the line of nodes defines the line of intersection of the ______________ plane and the ______________ plane.

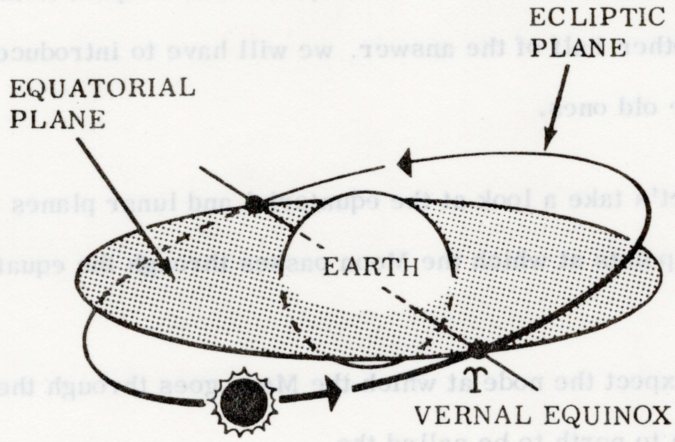


FIGURE 1-10.

1-16	

ANS-15: lunar

equatorial

Figure 1-10 shows the intersection of another pair of planes, the equatorial and the ecliptic. As you know, the vernal and autumnal equinoxes are both determined by this line of intersection. Notice that, if we look at things geocentrically, the equinoxes can be thought of as nodes in the Sun's orbit around Earth.

16. The vernal equinox can be thought of as the Sun's ________________ (ascending/descending) node.

1-17	

ANS-16: ascending

The Sun's ascending node is, of course, a fixed point on the celestial sphere. By definition, its right ascension and declination both equal zero.

17. Since the Moon's nodes lie in the equatorial plane, the declination of the ascending node is always zero. Would you expect its right ascension to also always be zero? ________________

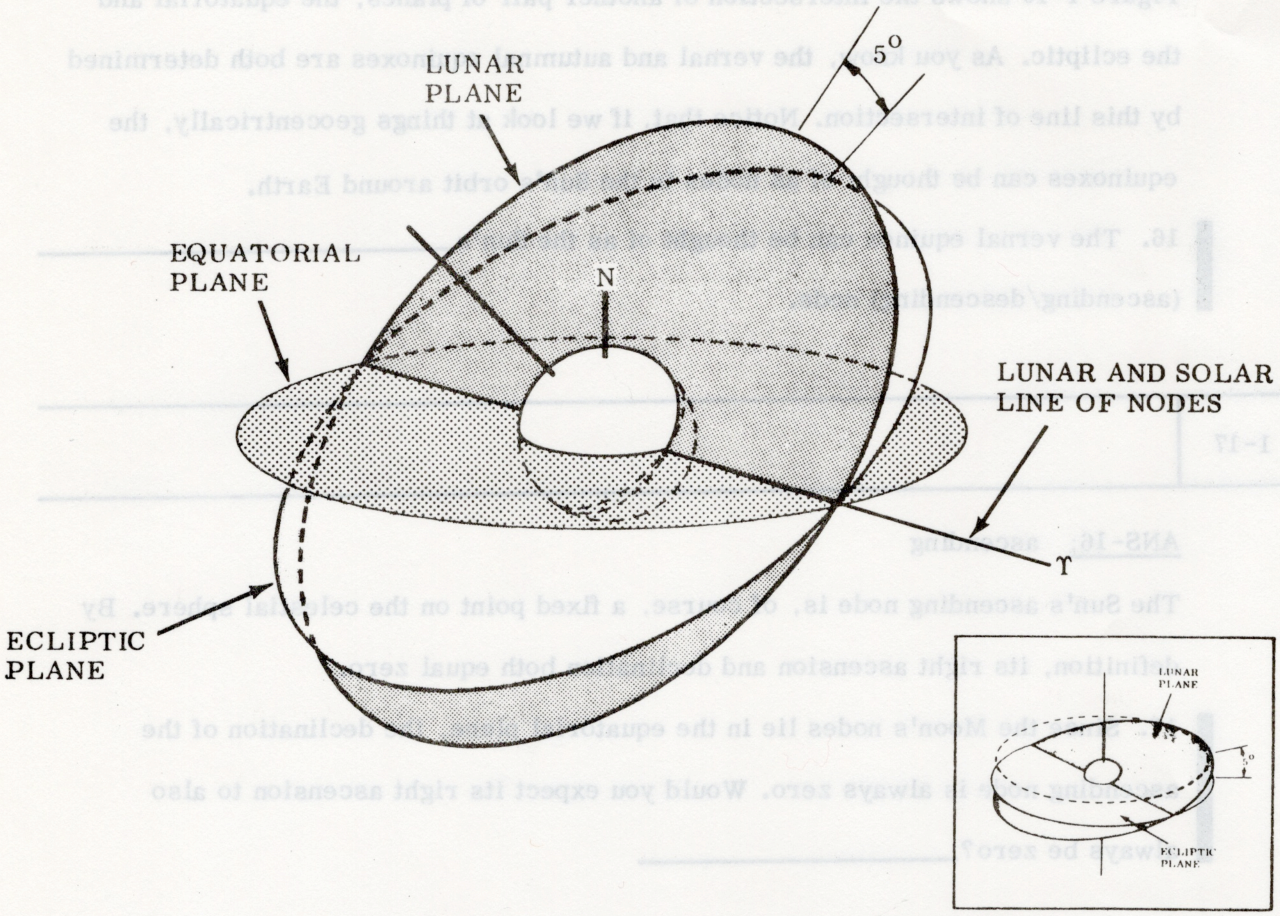

LUNAR PLANE
5°
EQUATORIAL PLANE
N
LUNAR AND SOLAR LINE OF NODES
♈
ECLIPTIC PLANE
LUNAR PLANE
5°
ECLIPTIC PLANE

FIGURE 1-11.

ANS-17: no

Remember that the lunar plane rotates about an axis perpendicular to the ecliptic. This means that the Moon's ascending node is continually moving. To see just how it is moving, we have to put the three planes back together, as shown in figure 1-11. Notice that the lunar plane is shown in a position corresponding to section A of figure 1-3. At this point in time, the two lines of nodes--lunar and solar--coincide.

18. In figure 1-11, the right ascension of the ascending lunar node is ______ hours.

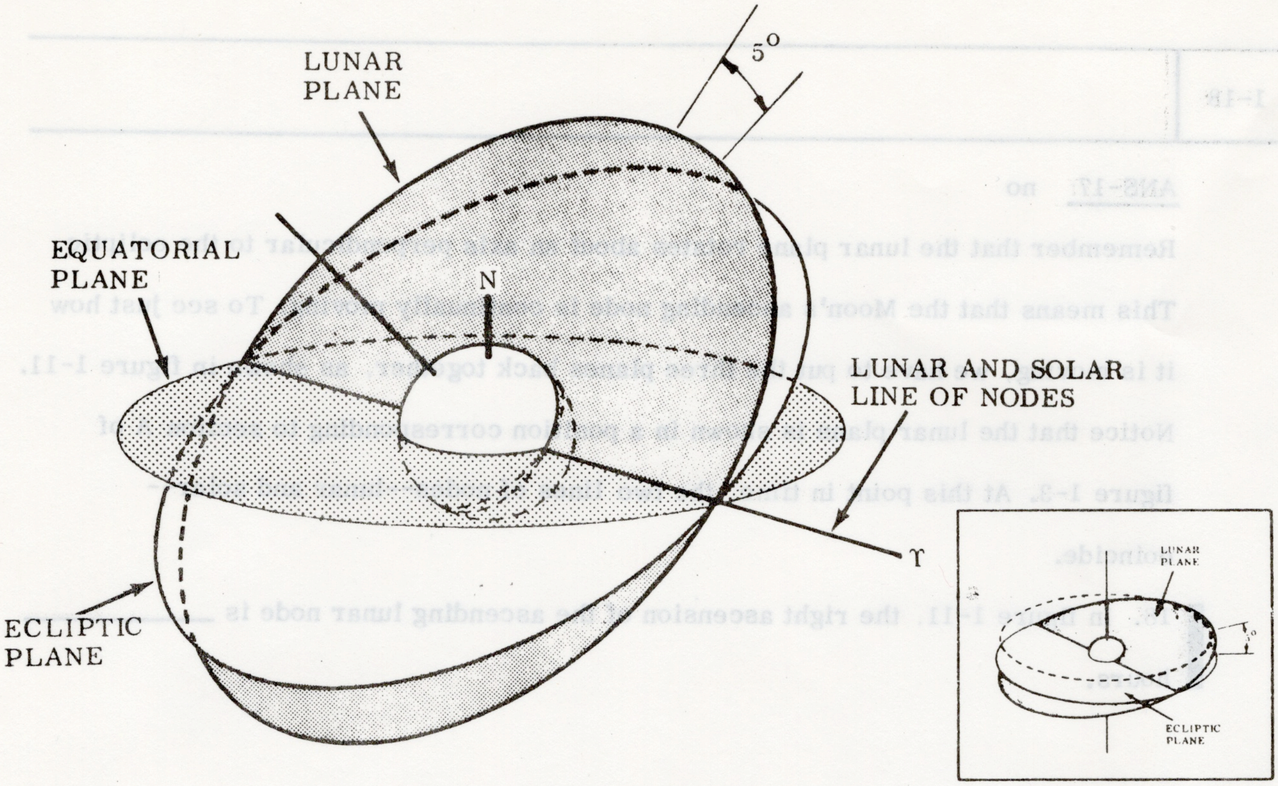


FIGURE 1-11.

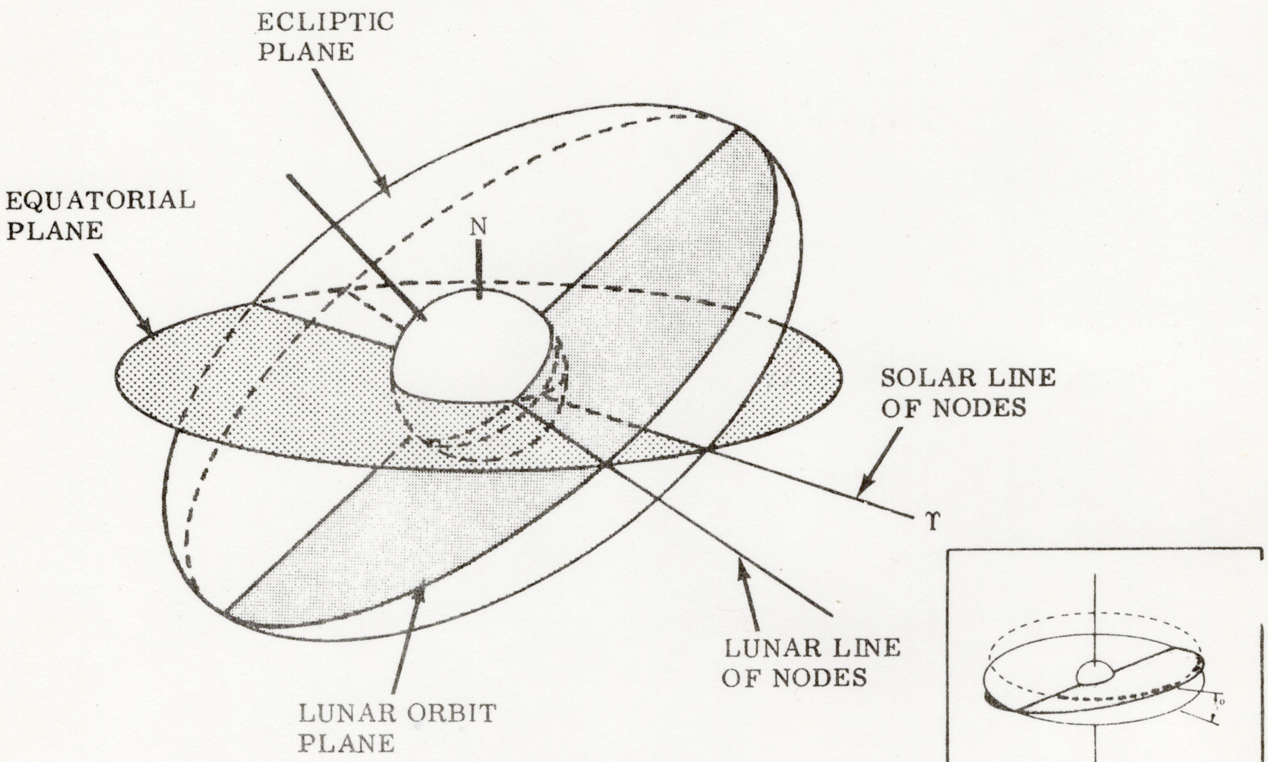


FIGURE 1-12.

ANS-18: zero

Now let's rotate the lunar plane 90°, to a position corresponding to section B of figure 1-3. This is shown in figure 1-12.

19. While the lunar plane itself has rotated 90° about the axis perpendicular to the ecliptic, the ascending node of the lunar orbit has moved ______________________________ (more than 90°/less than 90°/exactly 90°).

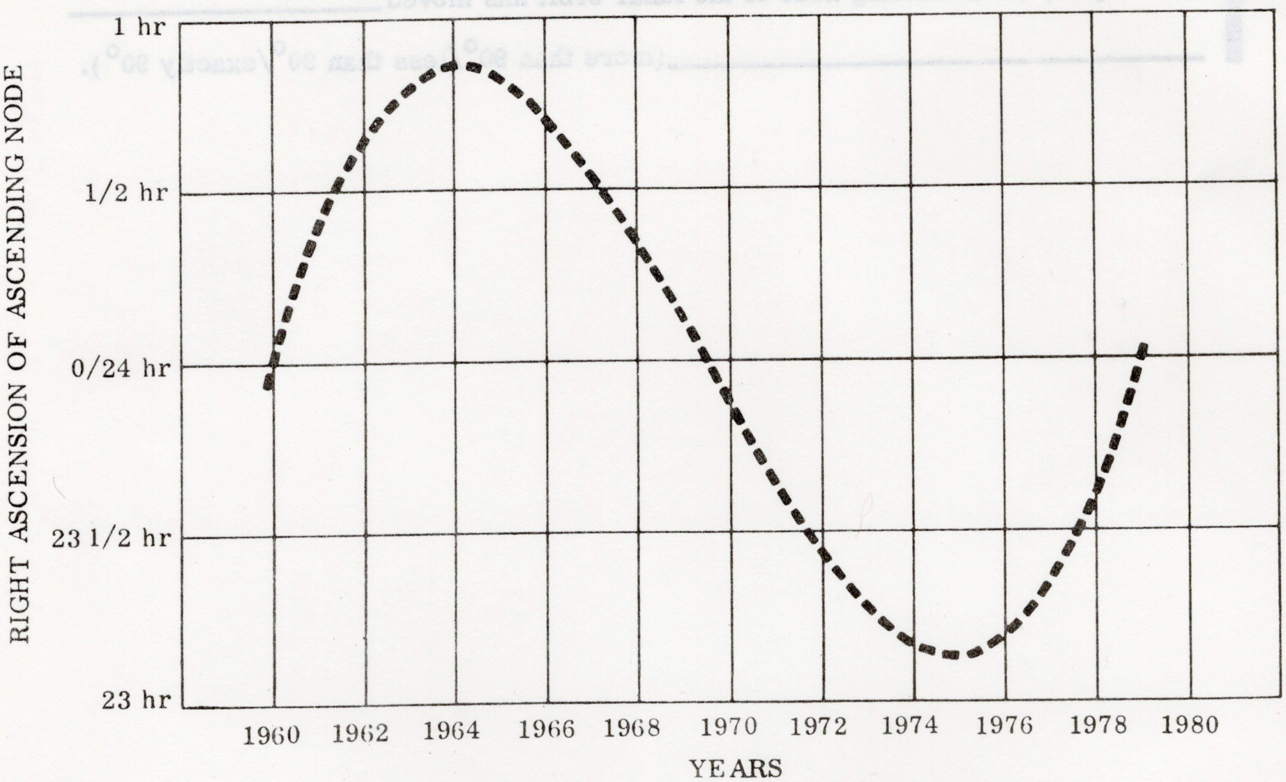

RIGHT ASCENSION OF ASCENDING NODE
1 hr
1/2 hr
0/24 hr
23 1/2 hr
23 hr
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
YEARS

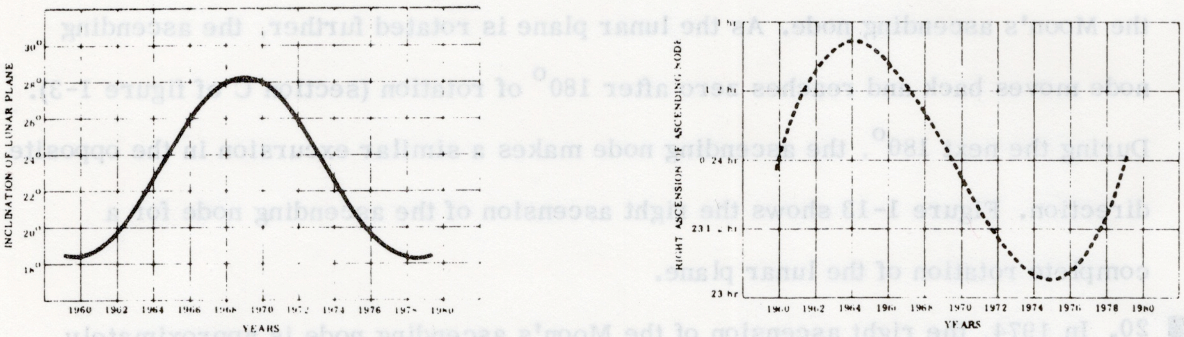
FIGURE 1-13.

1-20	

<u>ANS-19:</u> less than 90°

Actually, it has moved about 14°, or slightly less than one hour, which is the normal way of measuring right ascension. This is the maximum right ascension of the Moon's ascending node. As the lunar plane is rotated further, the ascending node moves back and reaches zero after 180° of rotation (section C of figure 1-3). During the next 180°, the ascending node makes a similar excursion in the opposite direction. Figure 1-13 shows the right ascension of the ascending node for a complete rotation of the lunar plane.

20. In 1974, the right ascension of the Moon's ascending node is approximately ______________________. Its descending node would be at approximately ______________________.



INCLINATION OF
LUNAR PLANE = i

RIGHT ASCENSION OF
ASCENDING NODE = Ω

FIGURE 1-14.

ANS-20: 23 hr

11 hr

So, we now have both parts of our answer to the question in frame 1-5. The effects of the lunar plane's rotation can be summed up in figure 1-14. Notice that we have assigned symbols to the two variables so they will be more convenient to refer to in the following frames.

21. The symbol for the angle between the lunar and equatorial planes is ________ .

22. The symbol for the angle between the first point of Aries and the Moon's ascending node (i.e., the right ascension of the Moon's ascending node) is _____ .

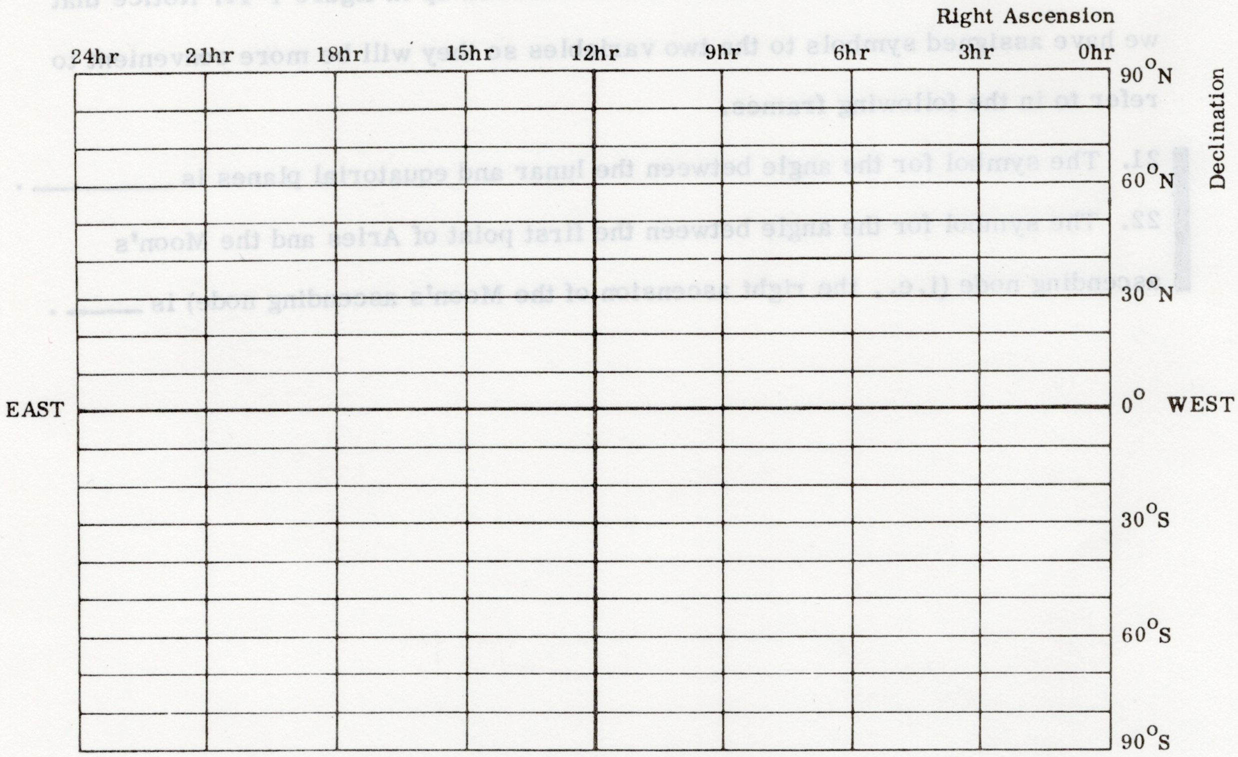

Right Ascension
24hr
21hr
18hr
15hr
12hr
9hr
6hr
3hr
0hr
Declination
90°N
60°N
30°N
0°
30°S
60°S
90°S
EAST
WEST

FIGURE 1-15.

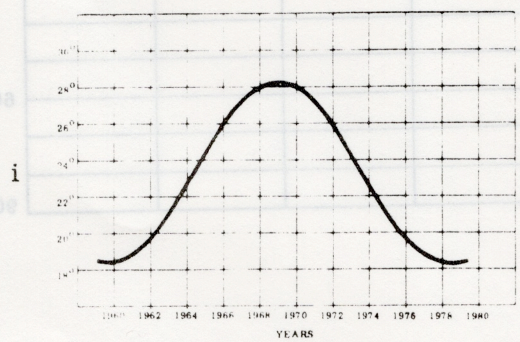
ANS-21: i

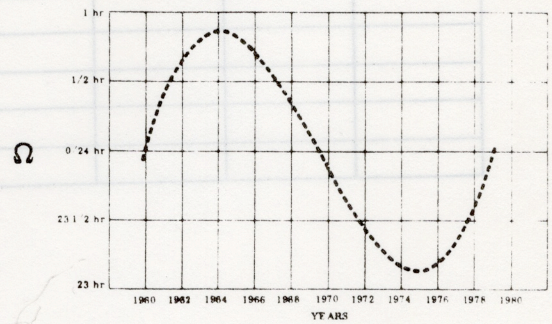
ANS-22: Ω

Now that we can determine i and Ω of the lunar orbit for any given year, it is a simple matter to plot the Moon's approximate path on a star chart.

The Moon's path is plotted much the same way as is the Sun's. Let's go through the process for the year 1960 using a simplified star chart like the one in figure 1-15.

23. As a first step, mark the ascending and descending lunar nodes on figure 1-15. Use figure 1-14, repeated below.





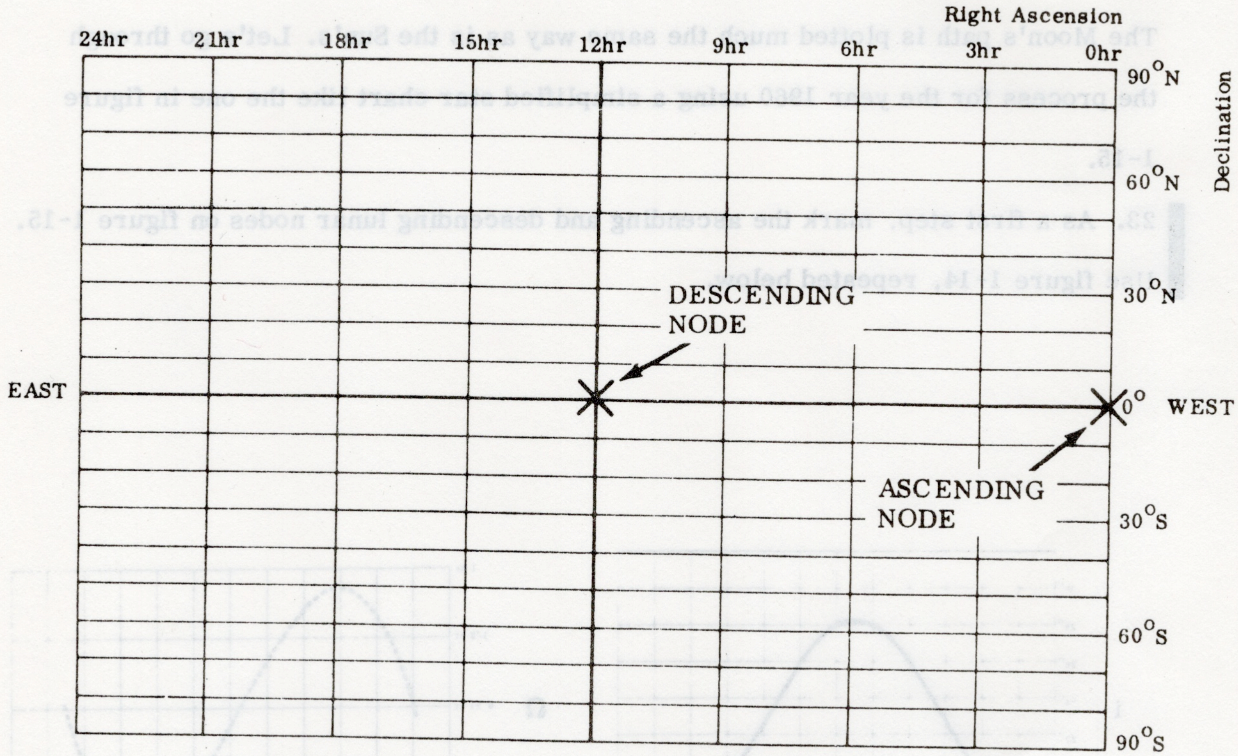
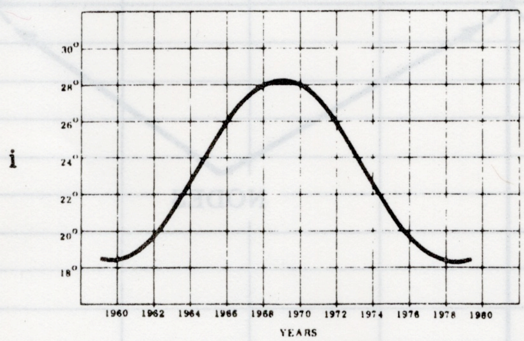

Right Ascension
24hr
21hr
18hr
15hr
12hr
9hr
6hr
3hr
0hr
90°N
60°N
30°N
0°
30°S
60°S
90°S
Declination
EAST
WEST
DESCENDING NODE
ASCENDING NODE

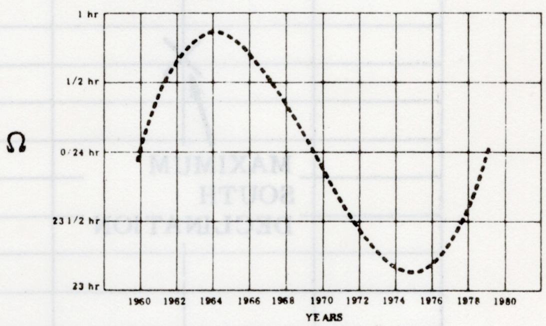
FIGURE 1-16.

ANS-23: See figure 1-16.

According to the graph in figure 1-14, the right ascension of the ascending node is approximately zero. Since the descending node is always 12 hours away from the ascending node, it is approximately 12 hours.

24. Again using the graphs in figure 1-14, mark the approximate points in figure 1-16 at which maximum northern and southern declinations occur.





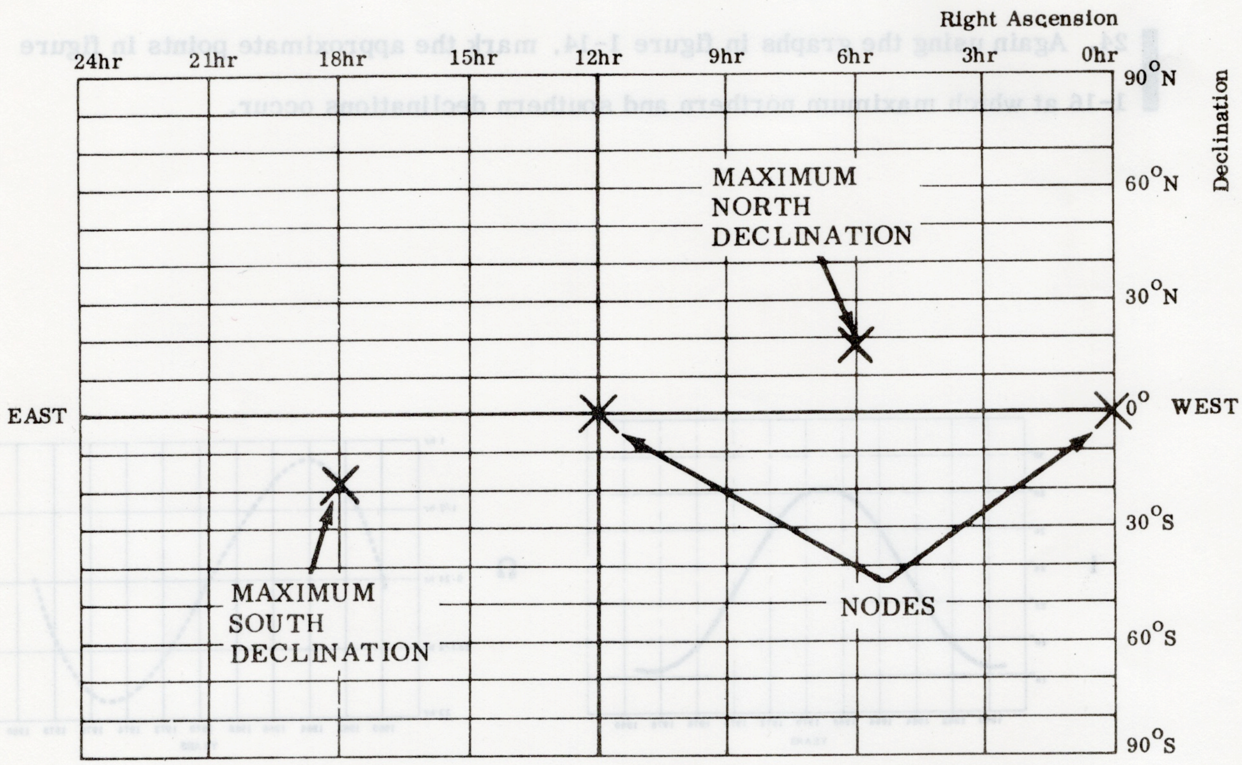

Right Ascension
24hr
21hr
18hr
15hr
12hr
9hr
6hr
3hr
0hr
Declination
90°N
60°N
30°N
0°
30°S
60°S
90°S
EAST
WEST
MAXIMUM NORTH DECLINATION
MAXIMUM SOUTH DECLINATION
NODES

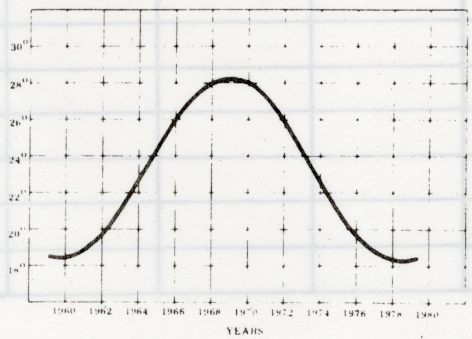
FIGURE 1-17.

ANS-24: See figure 1-17

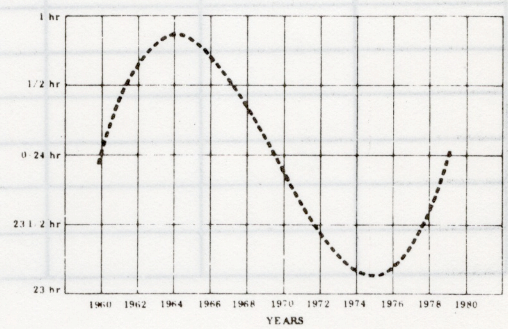
The graph in figure 1-14 gives us i = 18 1/2° for 1960. Therefore the maximum declination of the Moon in 1960 is 18 1/2°. As with the Sun, these points of maximum declination occur midway between the nodes. The maximum north declination, of course, occurs 6 hours after the ascending node, while the maximum south declination is 6 hours past the descending node.

25. Connect the four points to obtain the lunar path across the star chart.

i



Ω



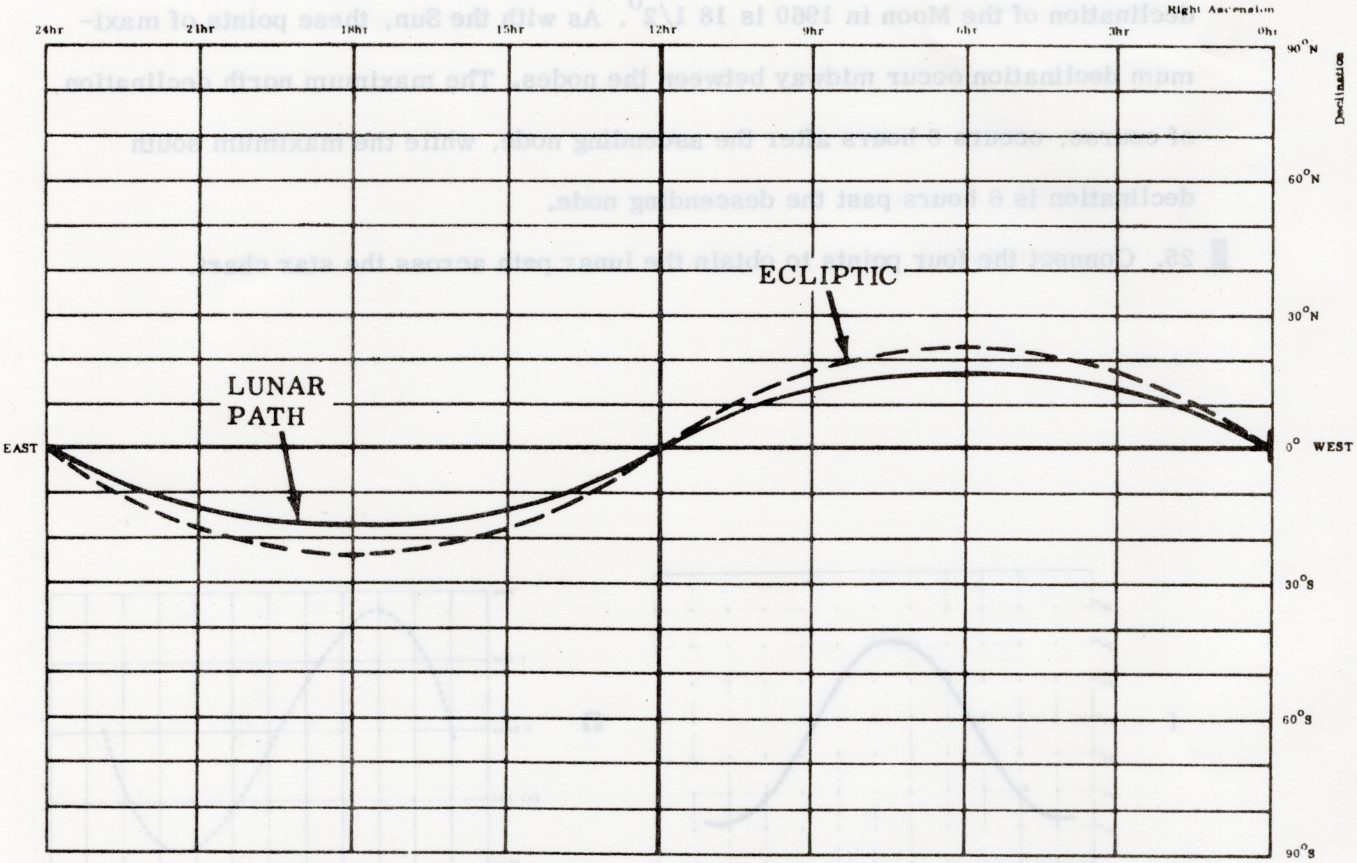

Right Ascension
24hr
21hr
18hr
15hr
12hr
9hr
6hr
3hr
0hr
Declination
90°N
60°N
30°N
0° WEST
EAST
30°S
60°S
90°S
ECLIPTIC
LUNAR PATH

FIGURE 1-18.

1-25	

ANS-25: See figure 1-18.

The path of the Moon appears to be very similar to that of the Sun, except that the Moon's path has less "amplitude".

If you are careful, you might even say that the two paths are "in phase". However, don't let this "in phase" idea mislead you. You must remember that the Moon crosses the star chart once every sidereal month (27 1/3 days), while the Sun crosses it once a year (365 1/4 days).

26. Just as the Sun's path on the star chart can be divided into months, the Moon's path could be divided into ______________________.

1-26	

ANS-26: days

Since the Moon crosses the star chart once every 27 1/3 days, it would seem only logical to divide the Moon's path into 27 1/3 days. For our purposes, however, it will be accurate enough to simply divide the month into 27 days.

27. Assume the mark near the ascending node in figure 1-18 represents midnight between January 4 and 5. Divide the lunar path into days and label each day (Jan. 5, 6, 7, etc). (NOTE: We have made the star chart exactly 6 3/4 inches wide, which means that each day is 1/4 inch wide.)

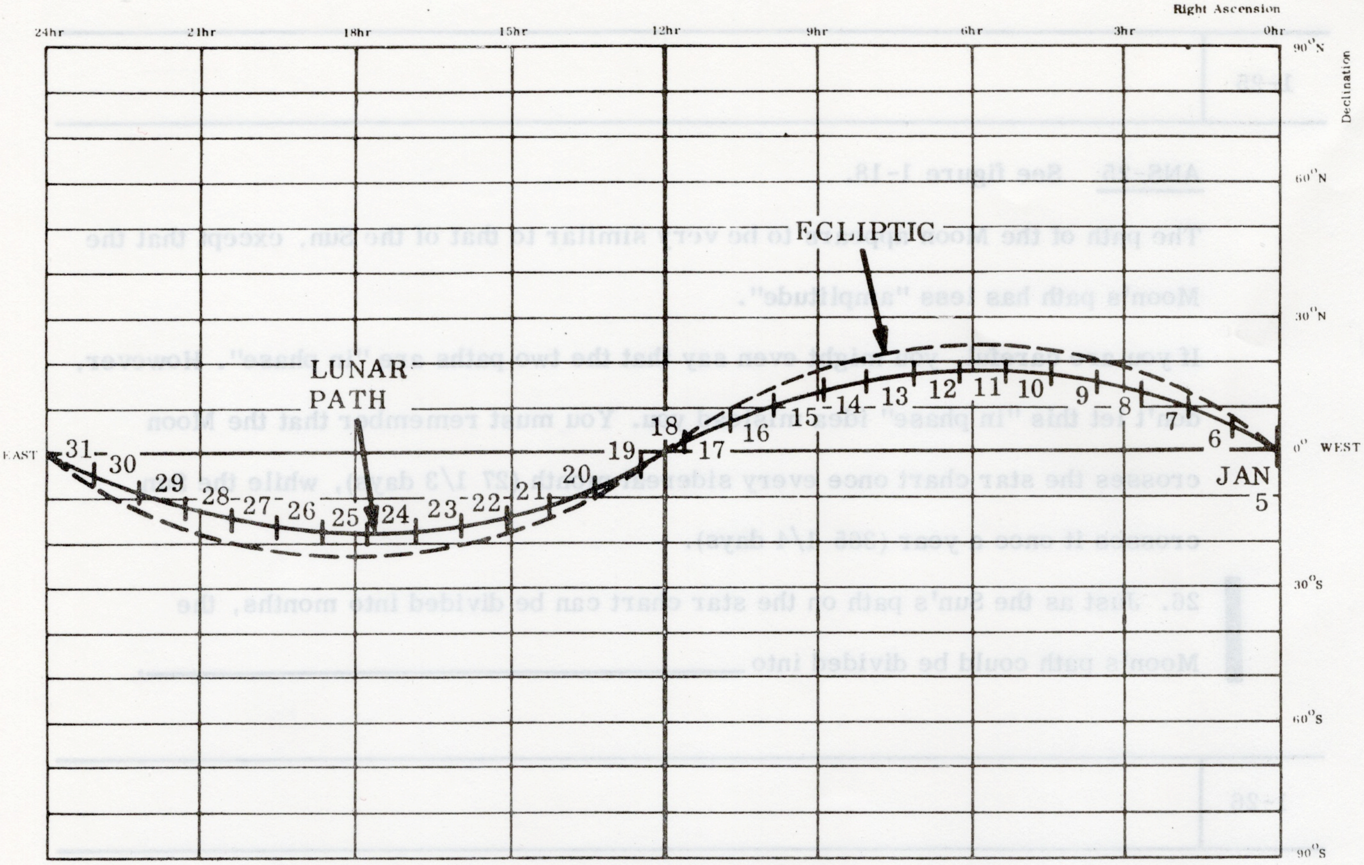


FIGURE 1-19.

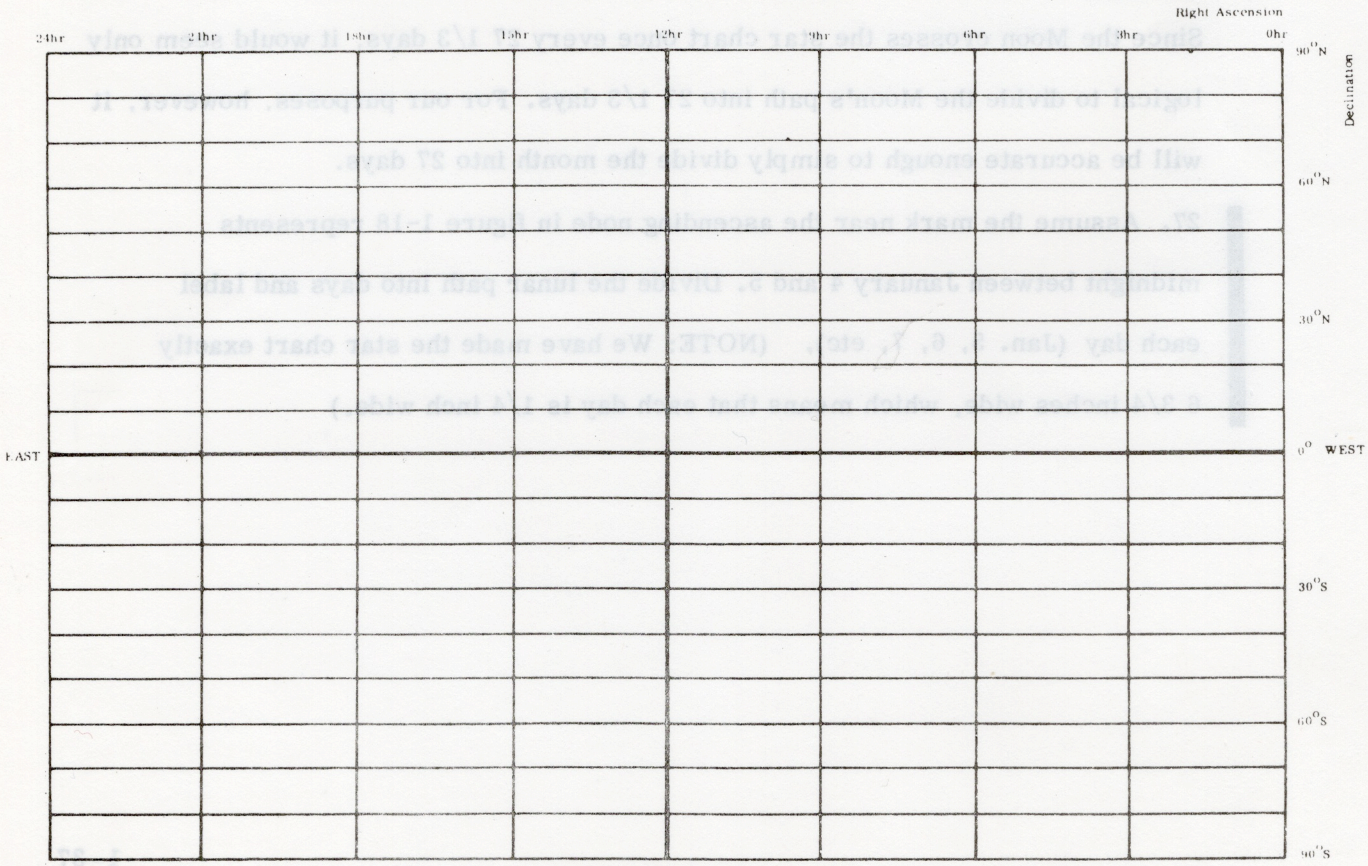
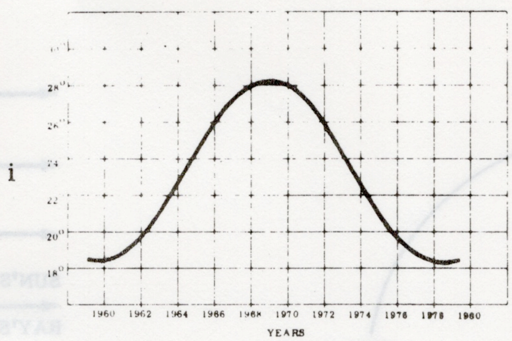


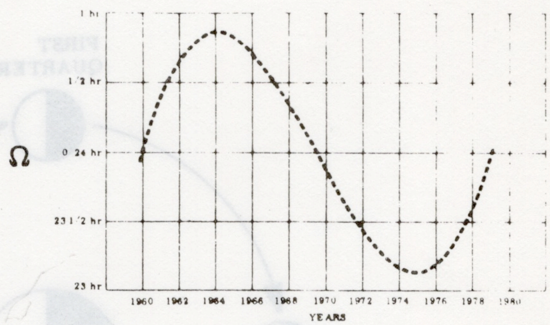
FIGURE 1-20.

ANS-27: See figure 1-19.

Notice that, if you wished, you could divide each day into hours. That is, at the beginning of January 5 (midnite), the Moon is at 0 hours right ascension. By noon, it is at almost 1/2 hour, and by the end of the day, it has nearly reached 1 hour (53 minutes, to be exact). For this kind of division, however, we would need a more accurate chart and would have to use the full 27 1/3 divisions.

28. Now that you have seen how easy plotting the Moon's path is, let's try it for another year. Using figure 1-20, plot the approximate path of the Moon for the year 1964. Use figure 1-14 (repeated below) to find i and Ω .





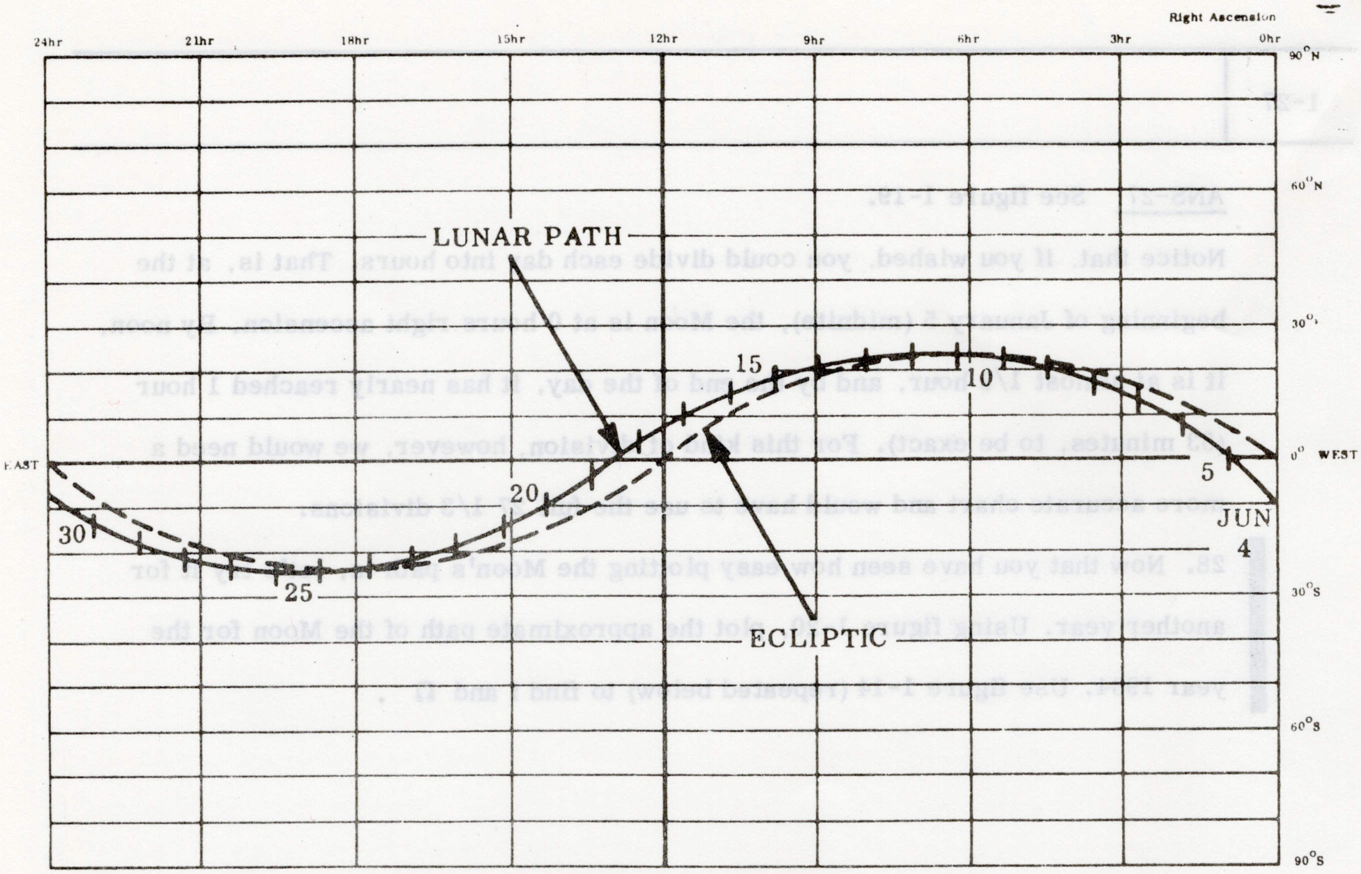


FIGURE 1-21.

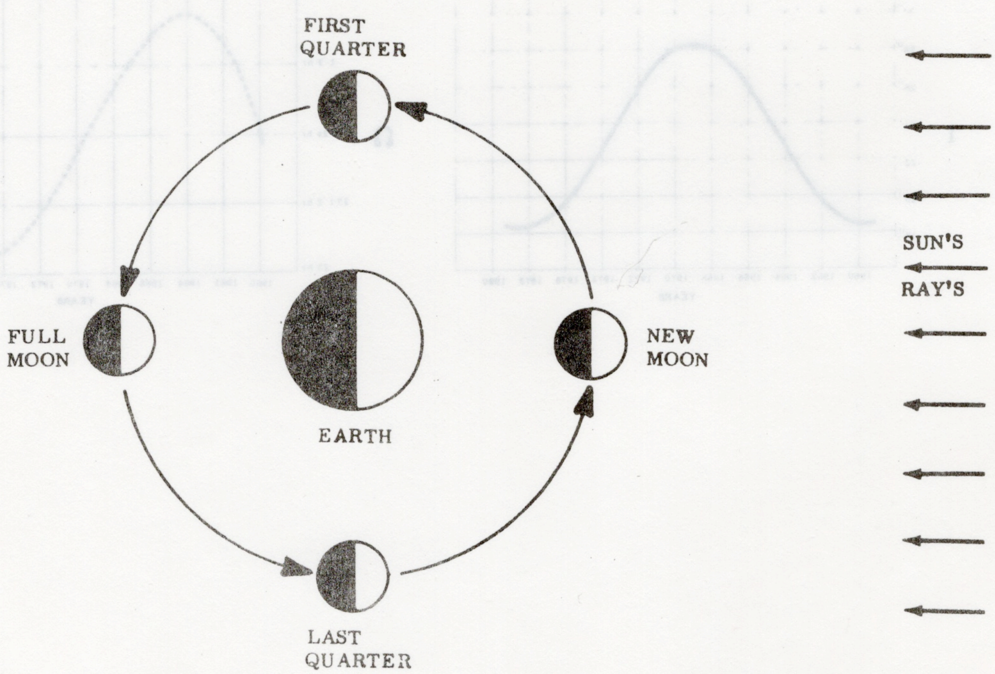


FIGURE 1-22.

1-28

ANS-28: See figure 1-21.

In 1964, the Moon's path had the same amplitude as the ecliptic, but it was shifted approximately one hour to the east. Notice that the lunar path--already divided into days--is for the month of June.

29. The Moon's ascending node occurs approximately at midnite between what two days? ____________________

30. The descending node occurs on what day? ____________________

1-29

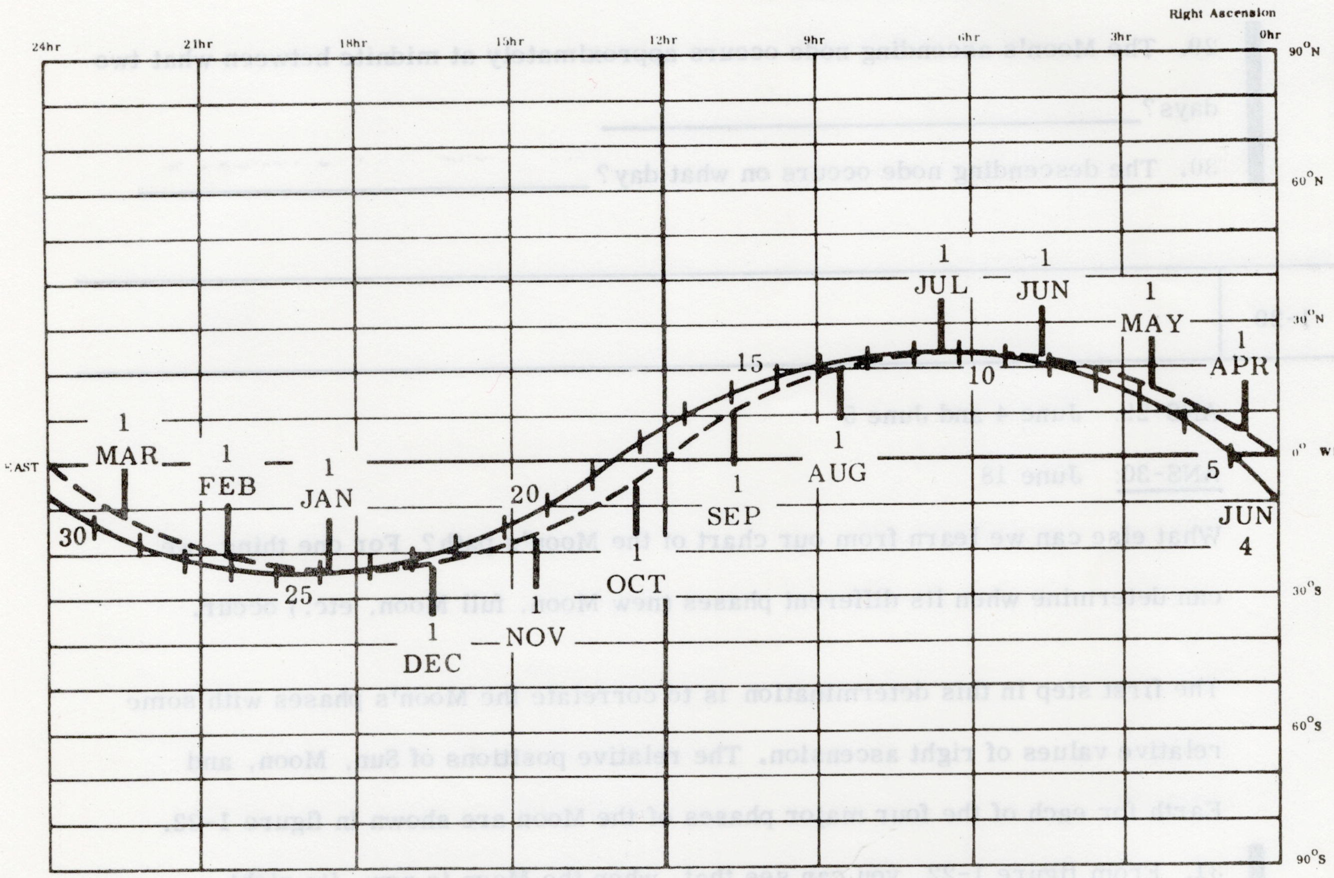
ANS-29: June 4 and June 5

ANS-30: June 18

What else can we learn from our chart of the Moon's path? For one thing, we can determine when its different phases (new Moon, full Moon, etc.) occur.

The first step in this determination is to correlate the Moon's phases with some relative values of right ascension. The relative positions of Sun, Moon, and Earth for each of the four major phases of the Moon are shown in figure 1-22.

31. From figure 1-22, you can see that, when the Moon is new, its right ascension is ____________________ (the same as the Sun's/12 hours more than the Sun's/6 hours more than the Sun's).



Right Ascension
24hr
21hr
18hr
15hr
12hr
9hr
6hr
3hr
0hr
90°N
Declination
60°N
30°N
0° WEST
EAST
30°S
60°S
90°S
1 MAR
1 FEB
1 JAN
1 DEC
1 NOV
1 OCT
1 SEP
1 AUG
1 JUL
1 JUN
1 MAY
1 APR
30
25
20
15
10
5
JUN 4

FIGURE 1-23.

1-30

ANS-31: the same as the Sun's

Now, knowing that a new Moon will have the same right ascension (but not necessarily the same declination) as the Sun, we can use the lunar path, marked off in days, and the ecliptic, marked off in months, to find the date of the new Moon for June, 1964.

32. Obviously, if the lunar and solar right ascensions are to be the same, it must be somewhere along the June section of the ecliptic. The only days in which the Moon is in the June section of the ecliptic are ______________________,

______________________, and ______________________.

1-31

ANS-32: June 9, 10, and 11

This narrows things down considerably. The new Moon will have to occur on one of those three days. But which one? To find out, you have to mentally divide the June section of the ecliptic into days. (You can't do this with complete accuracy, of course, so a guesstimate will do.)

33. Locate the section of the ecliptic which corresponds to June 9, 10, and 11. Which of these days on the ecliptic falls within the same day as marked on the lunar path? ______________________

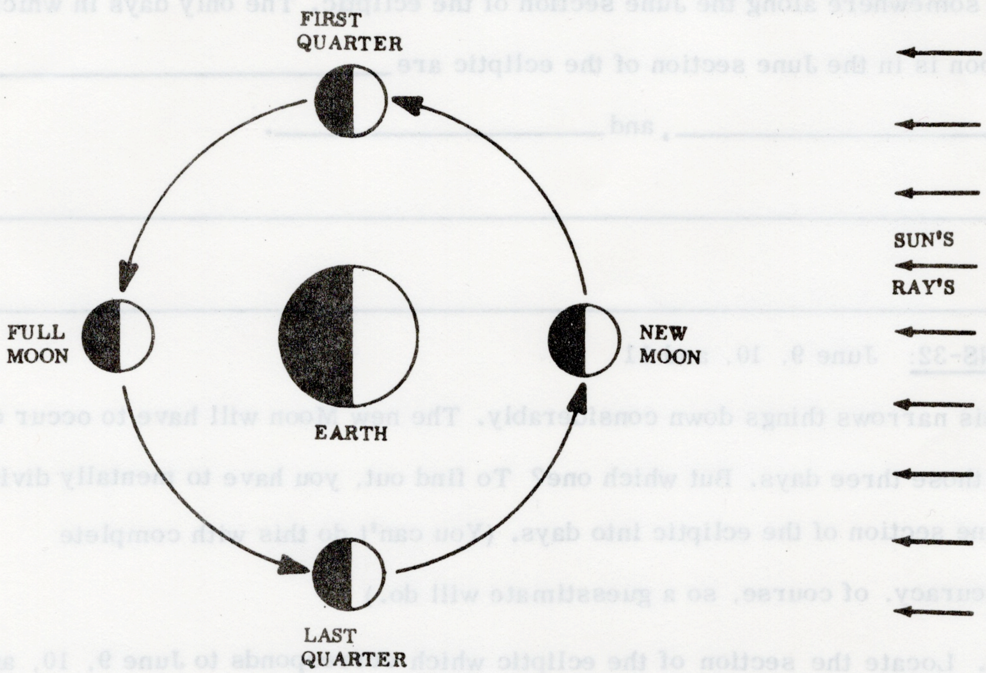

FIRST
QUARTER
FULL
MOON
EARTH
NEW
MOON
LAST
QUARTER
SUN'S
RAY'S

FIGURE 1-24.

1-32

ANS-33: June 9

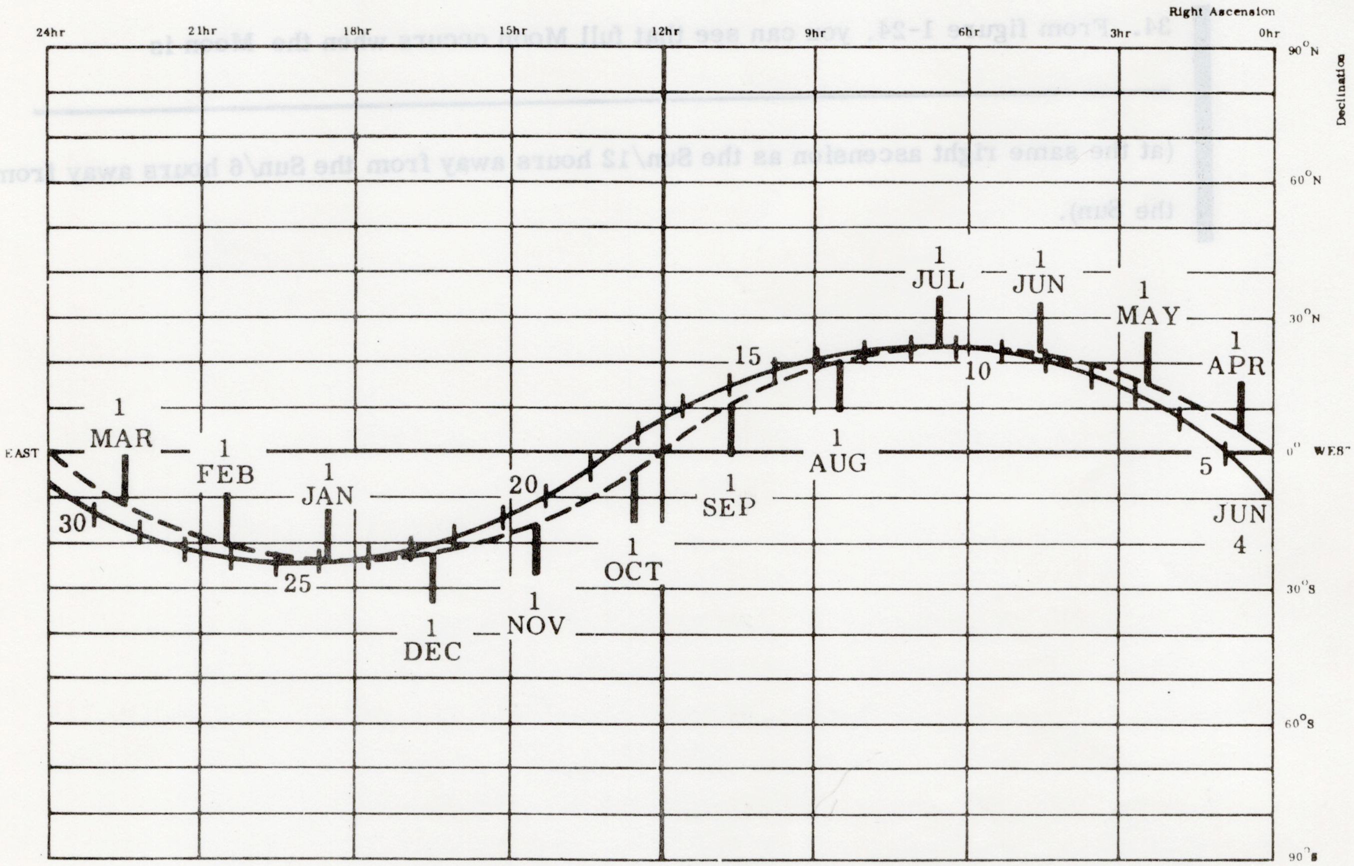
Actually, this particular new moon in 1964 occurred at about 10 P.M. on June 9, so if you said June 10, you only missed by a couple of hours.

Now, let's find the full Moon for the same month and year.

34. From figure 1-24, you can see that full Moon occurs when the Moon is

____

(at the same right ascension as the Sun/12 hours away from the Sun/6 hours away from the Sun).



Right Ascension
24hr
21hr
18hr
15hr
12hr
9hr
6hr
3hr
0hr
90°N
60°N
30°N
0°
30°S
60°S
90°S
Declination
EAST
WEST
1 MAR
1 FEB
1 JAN
1 DEC
1 NOV
1 OCT
1 SEP
1 AUG
1 JUL
1 JUN
1 MAY
1 APR
JUN 4
30
25
20
15
10
5

FIGURE 1-25.

1-33

ANS-34: 12 hours away from the Sun

Now, back to our star chart with the ecliptic and lunar path shown (figure 1-25). First, we see that the Sun's right ascension at new Moon is about 5 hours. Adding 12 to this gives us 17 hours, which puts us in the general neighborhood of June 23 on the lunar path.

35. In the meantime, however, the Sun has continued its motion along the ecliptic and by June 23 has reached approximately __________ hours right ascension.

1-34

ANS-35: 6

This means that, for the Moon to be 12 hours away from the Sun, it must be at 18 hours right ascension, not 17.

36. The full moon will occur on June __________.

1-35

ANS-36: 24

So, in terms of right ascension, the full Moon comes 13 hours after the new Moon. Similarly, the next new Moon will be 13 hours after the full Moon and almost 26 hours after the previous new Moon.

37. At what right ascension will the Moon be when the next full Moon (in late July) occurs? __________

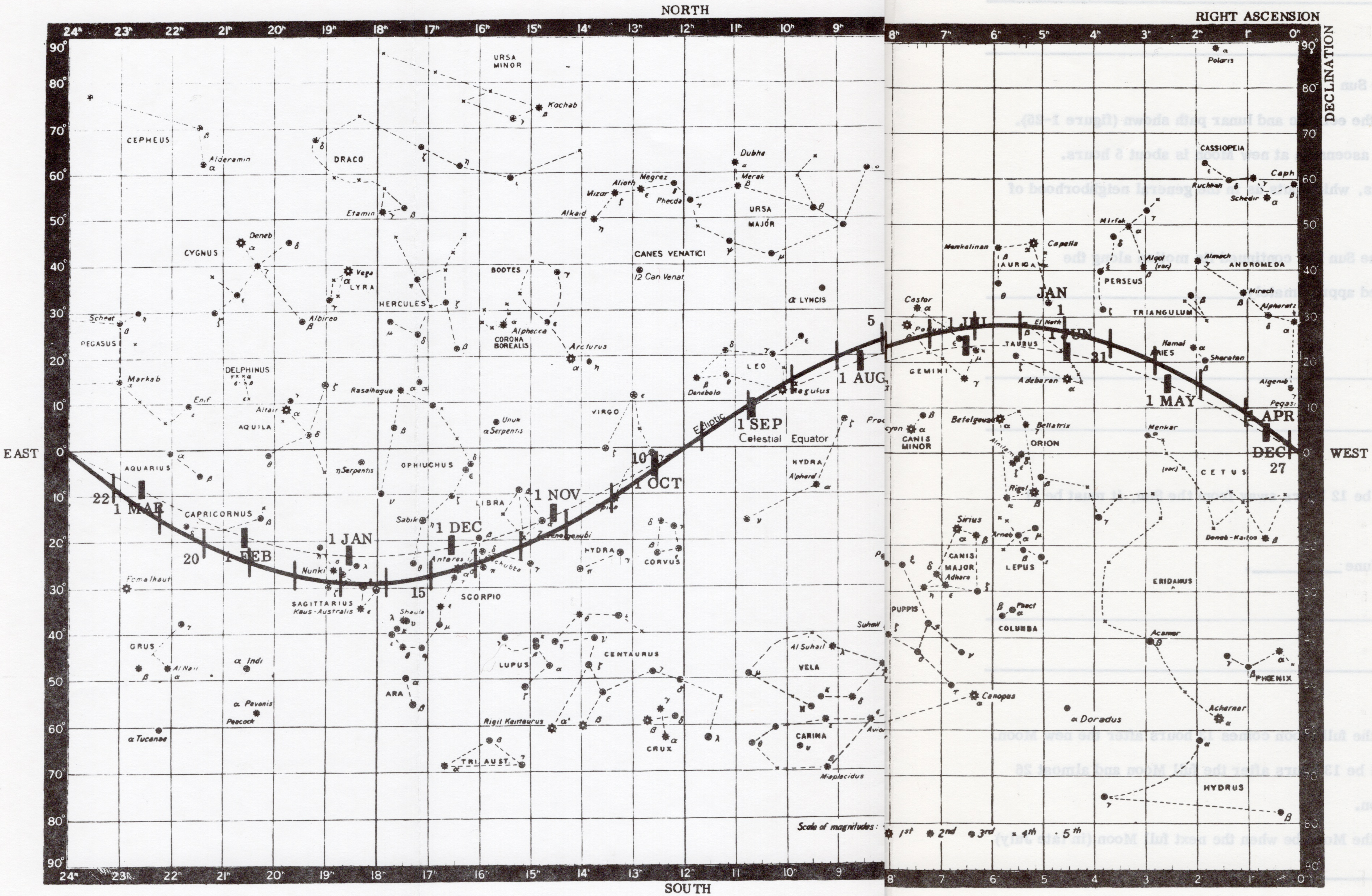

NORTH
SOUTH
EAST
WEST
RIGHT ASCENSION
DECLINATION
Ecliptic
Celestial Equator
URSA MINOR
Kochab
Polaris
CEPHEUS
Alderamin
DRACO
Etamin
Dubhe
Merak
Megrez
Alioth
Mizar
Alkaid
Phecda
URSA MAJOR
CANES VENATICI
12 Can Venat
CASSIOPEIA
Caph
Schedir
CYGNUS
Deneb
Albireo
Vega
LYRA
HERCULES
BOOTES
Arcturus
Alphecca
CORONA BOREALIS
α LYNCIS
Capella
AURIGA
Menkalinan
Mirfak
PERSEUS
Almach
ANDROMEDA
Mirach
Alpheratz
TRIANGULUM
Castor
Pollux
GEMINI
TAURUS
El Nath
Aldebaran
Hamal
ARIES
Sheratan
Algenib
Scheat
PEGASUS
Markab
Enif
DELPHINUS
Altair
AQUILA
Rasalhague
Unuk
α Serpentis
η Serpentis
OPHIUCHUS
VIRGO
LEO
Denebola
Regulus
Procyon
CANIS MINOR
Betelgeuse
Bellatrix
ORION
Rigel
Menkar
CETUS
AQUARIUS
CAPRICORNUS
LIBRA
HYDRA
Alphard
Spica
CORVUS
Sabik
Antares
SCORPIO
Shaula
Nunki
SAGITTARIUS
Kaus-Australis
Fomalhaut
Sirius
CANIS MAJOR
Adhara
LEPUS
ERIDANUS
Deneb-Kaitos
PUPPIS
COLUMBA
Phact
Suhail
Al Suhail
VELA
Canopus
α Doradus
Acamar
PHOENIX
Achernar
HYDRUS
GRUS
Al Nair
α Indi
α Pavonis
Peacock
α Tucanae
ARA
LUPUS
CENTAURUS
Rigil Kentaurus
CRUX
CARINA
Miaplacidus
TRI. AUST.
1 MAR
1 FEB
1 JAN
1 DEC
1 NOV
1 OCT
1 SEP
1 AUG
1 JUL
1 JUN
1 MAY
1 APR
DEC
27
JAN
22
20
15
10
5
31
Scale of magnitudes: 1st 2nd 3rd 4th 5th

FIGURE 1-26.

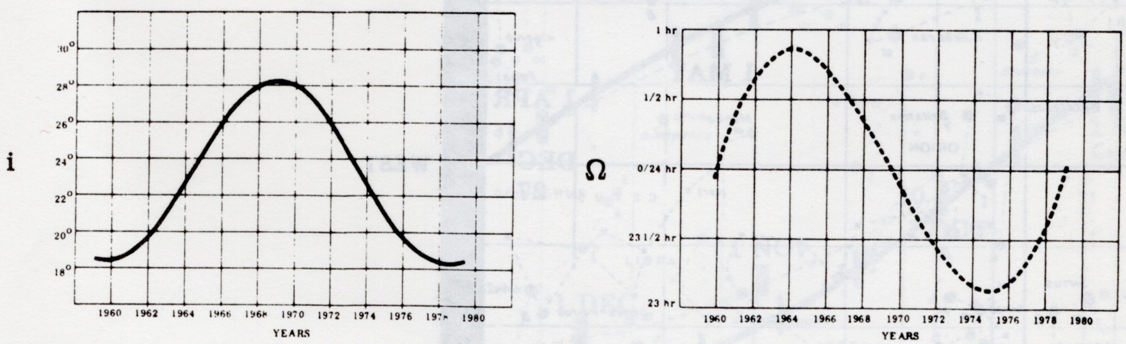
1-36

ANS-37: 20 hours

Full Moon in July equals full Moon in June (18 hr) plus 26 hr. The Sun, of course, will have moved to about 8 hr.

So far we haven't been concerned with the stars; we have only worked with the Moon and Sun and their paths across the star chart. In figure 1-26, we have a star chart with stars.

38. The lunar path shown in figure 1-26 is for the year________________ (1960/1964/1969/1974). (See figure 1-14, repeated below.)



1-37

ANS-38: 1969

Since the ascending node is at 0 hours, Ω is 0, which occurs only in 1960, 1969, and 1979. The maximum declination of 28 1/2°, rather than 18 1/2°, means the year must be 1969.

39. Indicate on figure 1-26 the position of the full Moon and the new Moon for the month shown. Remember, the new Moon is at the same right ascension as the Sun, while the full Moon is 12 hours away from the Sun.

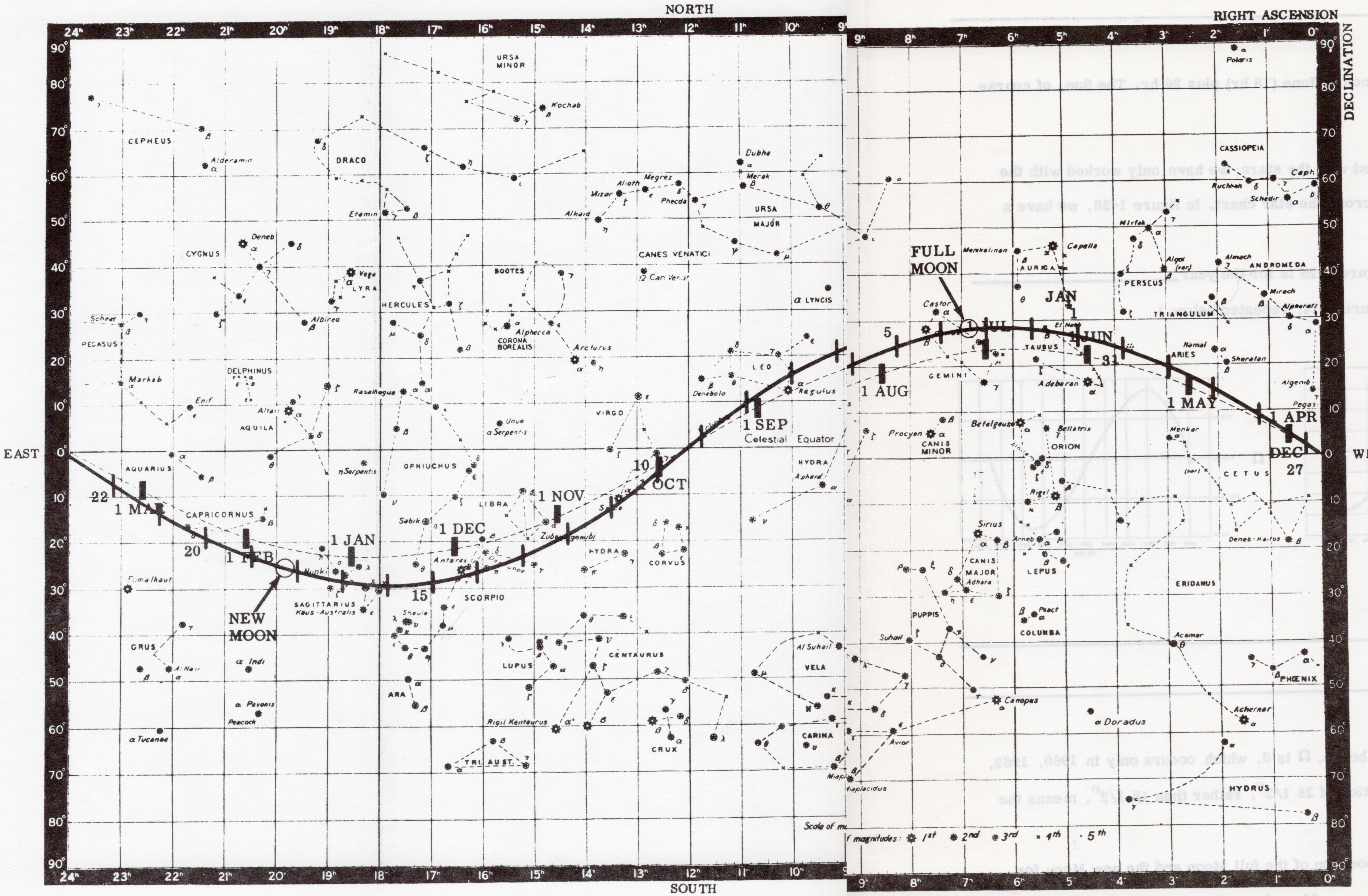

NORTH
RIGHT ASCENSION
DECLINATION
EAST
WEST
SOUTH
FULL MOON
NEW MOON
1 JAN
1 FEB
1 MAR
1 APR
1 MAY
JUN
JUL
1 AUG
1 SEP
1 OCT
1 NOV
1 DEC
DEC 27
Celestial Equator
URSA MINOR
Kochab
CEPHEUS
Alderamin
DRACO
Etamin
CYGNUS
Deneb
Vega
LYRA
Albireo
HERCULES
BOOTES
CORONA BOREALIS
Alphecca
Arcturus
CANES VENATICI
12 Can Ven
URSA MAJOR
Dubhe
Merak
Alioth
Megrez
Mizar
Phecda
Alkaid
α LYNCIS
PEGASUS
Scheat
Markab
Enif
DELPHINUS
Altair
AQUILA
Rasalhague
OPHIUCHUS
Unuk
α Serpentis
η Serpentis
VIRGO
LEO
Regulus
Denebola
AQUARIUS
CAPRICORNUS
LIBRA
Sabik
Antares
SCORPIO
SAGITTARIUS
Kaus Australis
Nunki
Shaula
HYDRA
Alphard
CORVUS
Zubenelgenubi
Fomalhaut
GRUS
Al Nair
α Indi
α Pavonis
Peacock
α Tucanae
ARA
LUPUS
CENTAURUS
Rigil Kentaurus
TRI. AUST.
CRUX
CARINA
VELA
Al Suhail
Miaplacidus
Scale of magnitudes: 1st 2nd 3rd 4th 5th
Polaris
CASSIOPEIA
Ruchbah
Schedir
Caph
Mirfak
Capella
Menkalinan
AURIGA
PERSEUS
Algol
Almach
ANDROMEDA
Mirach
Alpheratz
TRIANGULUM
Castor
El Nath
TAURUS
Aldebaran
GEMINI
Hamal
ARIES
Sheratan
Algenib
Pegasi
Betelgeuse
Bellatrix
ORION
Procyon
CANIS MINOR
Menkar
CETUS
Rigel
Sirius
Arneb
LEPUS
CANIS MAJOR
Adhara
Deneb Kaitos
ERIDANUS
PUPPIS
Suhail
Phact
COLUMBA
Acamar
PHOENIX
Canopus
Avior
α Doradus
Achernar
HYDRUS

FIGURE 1-27.

ANS-39: See figure 1-27.

The procedure for finding the new and full Moons in this instance is essentially the same as the one we have already used. The only difference is that the full Moon occurs first. It is easier, however, to locate the new Moon first. The new Moon for January would have to be between 18 1/2 and 20 1/2 hours right ascensicn, which would put it on either the 17th or the 18th. On these two days, the Sun would be a little more than halfway along the January section of the ecliptic, i.e., at slightly less than 20 hours right ascension. This places the new Moon early on the 18th. The full Moon would have occurred 13 hours of right ascension away, at just under 7 hours and on January 3. The Sun on January 3, of course, would be 12 hours away, at just under 19 hours right ascension.

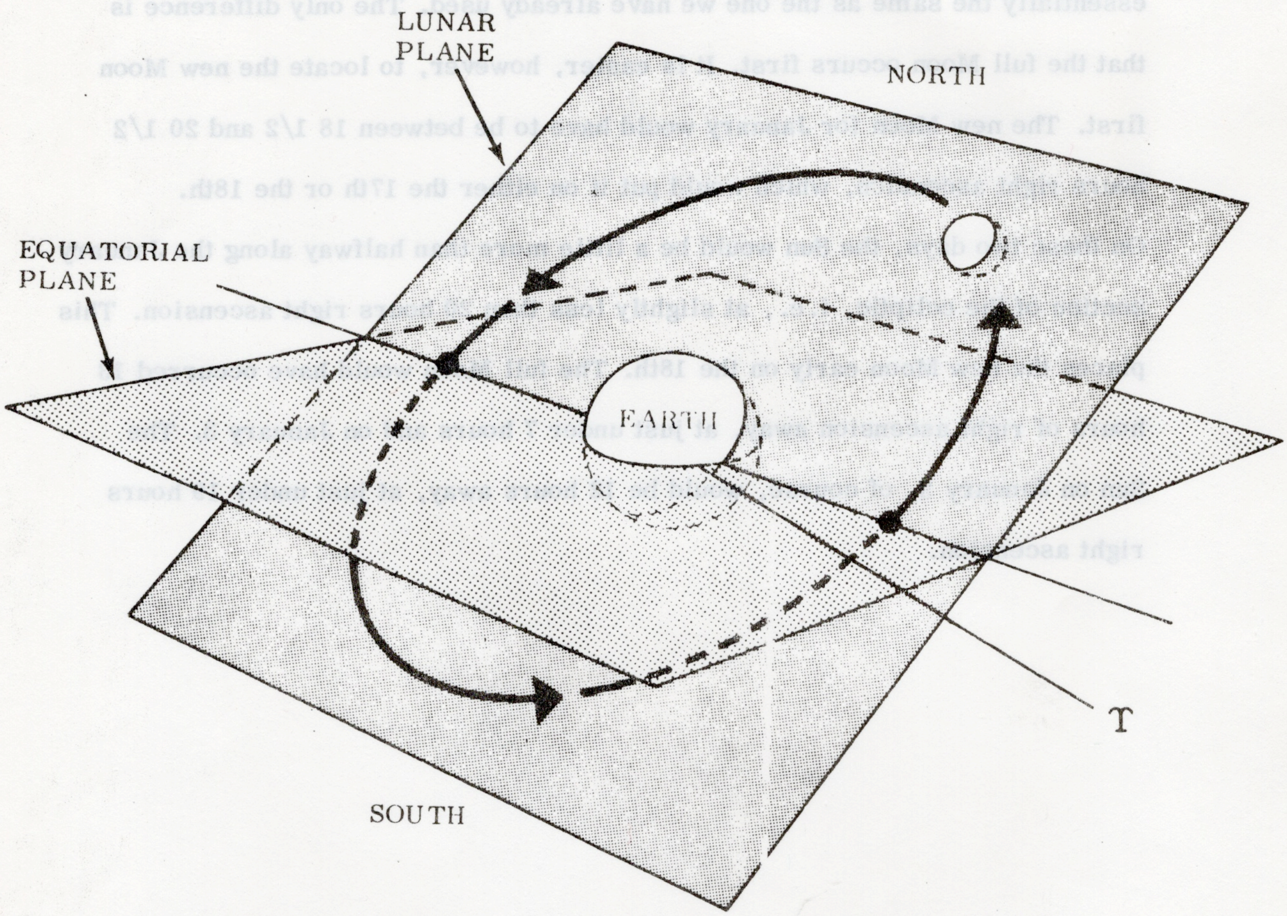


FIGURE 1-28.

40. In figure 1-28, label the ascending node of the lunar orbit and Ω .

41. The axis about which the lunar plane rotates is perpendicular to the ______________ (lunar/ecliptic/equatorial) plane.

42. As viewed from the north, the Moon itself rotates about Earth in a __________ (CW/CCW) direction, and the lunar plane rotates in a ______________ (CW/CCW) direction.

43. Assuming the inclination of the lunar plane with respect to the equatorial plane to be $28\ 1/2^{\circ}$ in 1969, in what year will this inclination again be $28\ 1/2^{\circ}$? ________

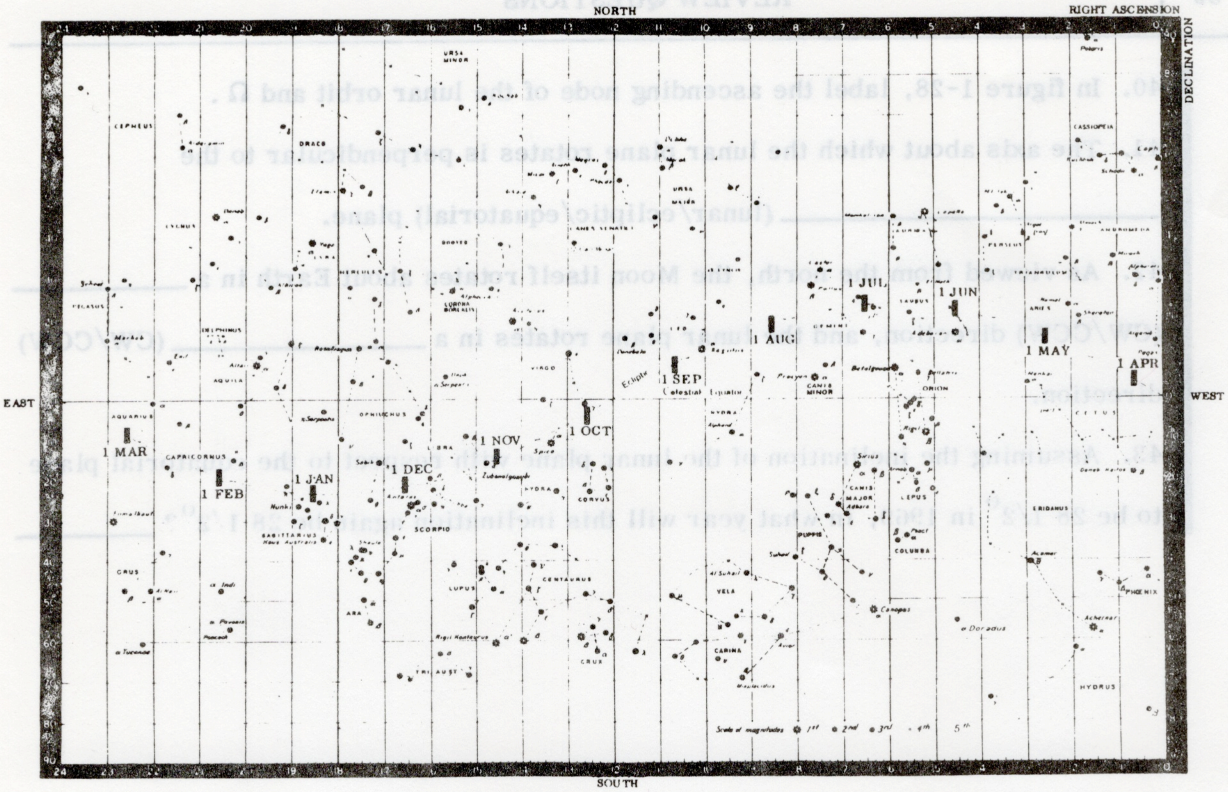


FIGURE 1-29

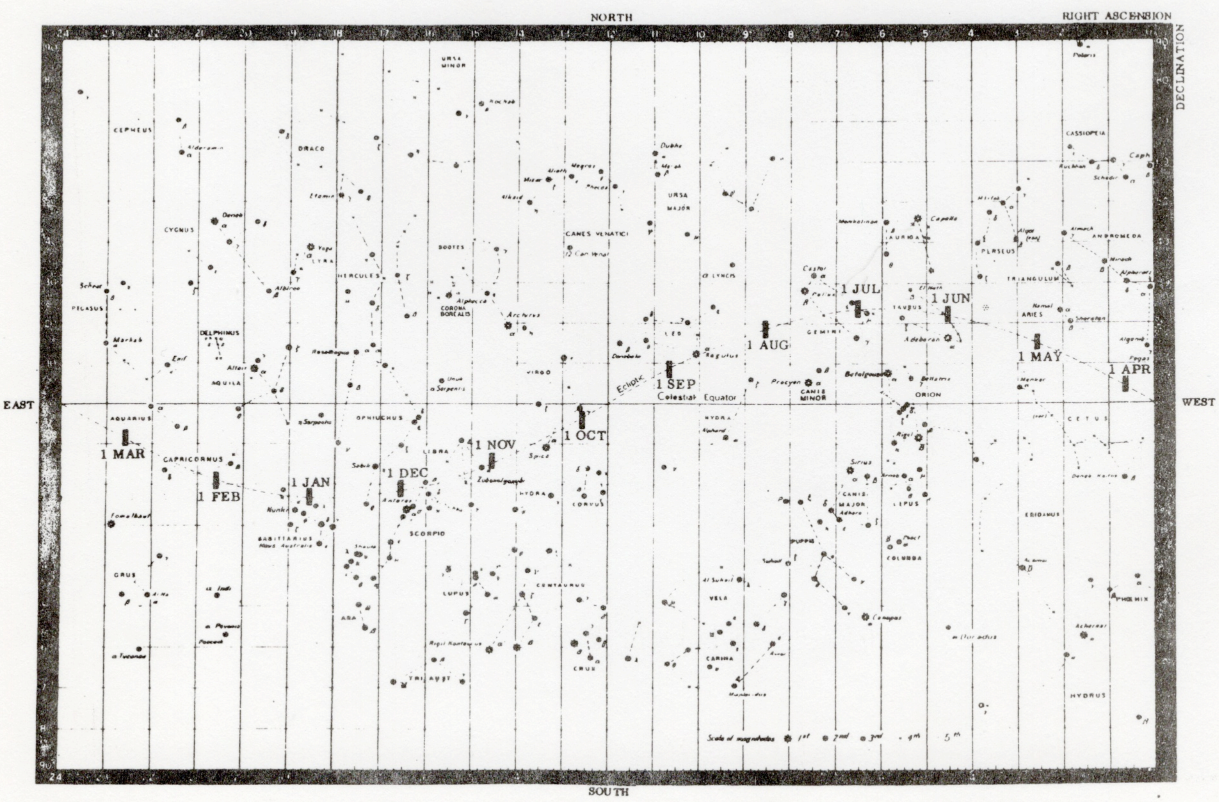
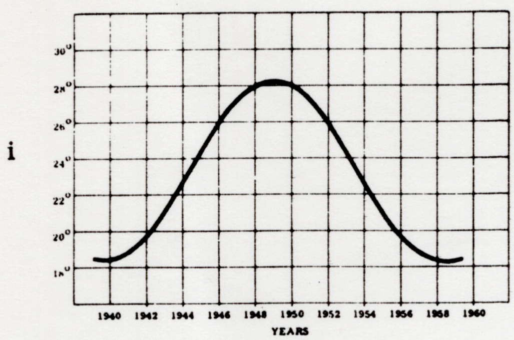
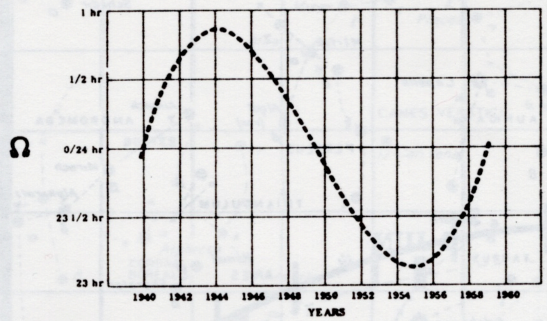


FIGURE 1-30.

44. Using the charts below, sketch the approximate lunar orbital path for 1949 in figure 1-29 and 1959 in figure 1-30.





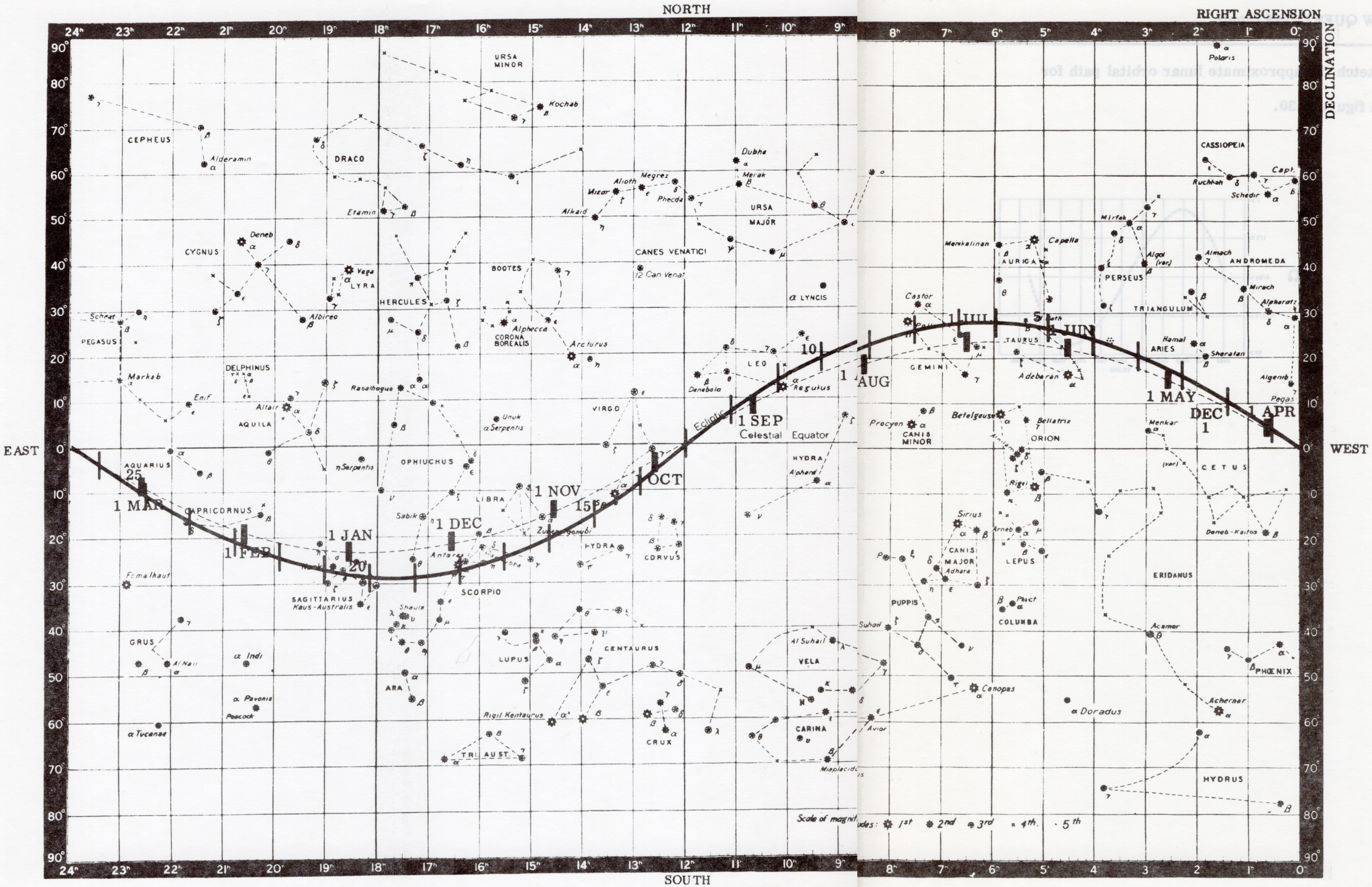

NORTH
RIGHT ASCENSION
DECLINATION
EAST
WEST
SOUTH
CEPHEUS
DRACO
URSA MINOR
Kochab
Alderamin
CYGNUS
Deneb
Albireo
Vega
LYRA
HERCULES
BOOTES
CORONA BOREALIS
Alphecca
Arcturus
CANES VENATICI
12 Can Venat
URSA MAJOR
Dubhe
Merak
Alioth
Megrez
Mizar
Phecda
Alkaid
Etamin
PEGASUS
Scheat
Markab
Enif
DELPHINUS
Altair
AQUILA
AQUARIUS
CAPRICORNUS
Fomalhaut
Rasalhague
OPHIUCHUS
η Serpentis
Unuk
α Serpentis
VIRGO
LEO
Regulus
Denebola
α LYNCIS
Ecliptic
Celestial Equator
HYDRA
Alphard
LIBRA
Sabik
Antares
SCORPIO
Zubenelgenubi
CORVUS
SAGITTARIUS
Kaus-Australis
Shaula
GRUS
Al Nair
α Indi
α Pavonis
Peacock
α Tucanae
ARA
LUPUS
CENTAURUS
Rigil Kentaurus
TRI AUST
CRUX
VELA
Al Suhail
CARINA
Miaplacidus
Avior
Scale of magnitudes: 1st 2nd 3rd 4th 5th
CASSIOPEIA
Ruchbah
Schedir
Caph
Polaris
Capella
Menkalinan
AURIGA
PERSEUS
Mirfak
Algol (var)
Almach
ANDROMEDA
Mirach
Alpheratz
TRIANGULUM
Hamal
ARIES
Sheratan
Algenib
Castor
GEMINI
TAURUS
Adebaran
Procyon
CANIS MINOR
Betelgeuse
Bellatrix
ORION
Rigel
Menkar
CETUS
Deneb-Kaitos
Sirius
CANIS MAJOR
Adhara
LEPUS
Arneb
PUPPIS
Suhail
COLUMBA
Phact
Canopus
α Doradus
ERIDANUS
Acamar
PHOENIX
Achernar
HYDRUS
1 MAR
25
1 FEB
1 JAN
20
1 DEC
1 NOV
15
OCT
1 SEP
10
1 AUG
1 JUL
5
1 JUN
1 MAY
DEC 1
1 APR

FIGURE 1-31.

45. Using figure 1-31, determine the date of the full Moon and the date of the new Moon for the month shown.

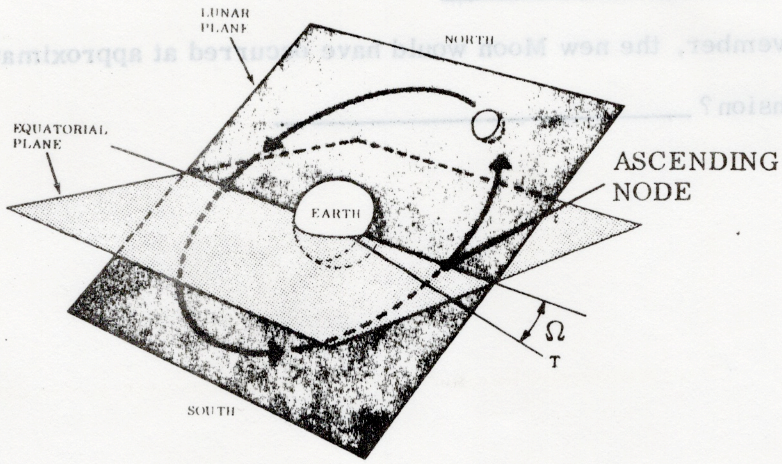
Full Moon ______________________

New Moon ______________________

During November, the new Moon would have occurred at approximately what right ascension? ____________________________

If you miss a question, review the frame or frames listed to the right of the answer.

ANS-40: 1-14 thru 1-22



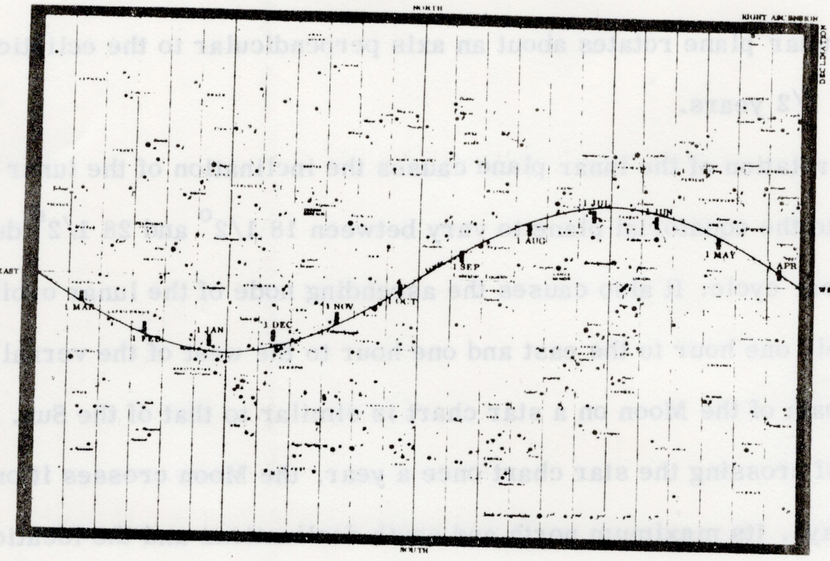
ANS-41: ecliptic 1-3, 1-4

ANS-42: CCW Figure 1-9

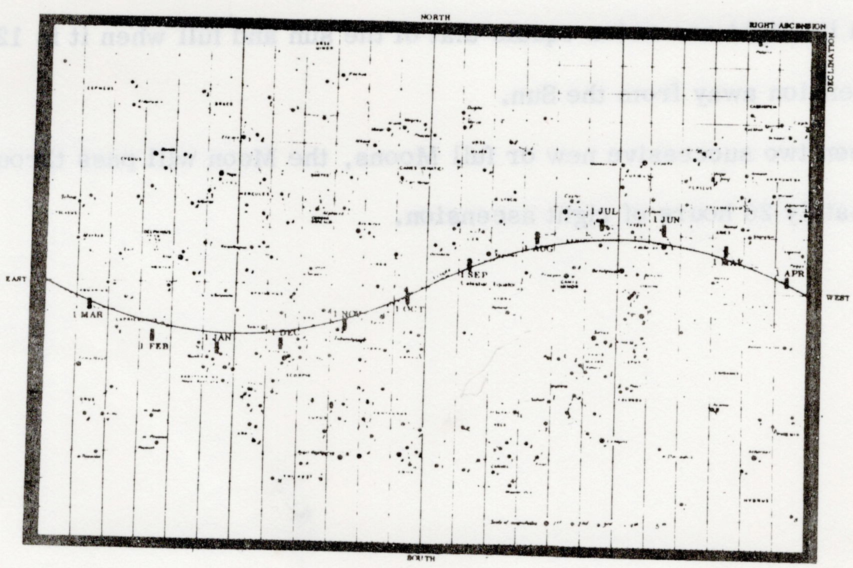
CW

ANS-43: 1987 or 1988 1-10

ANS-44: 1-22 thru 1-25



1949



1959

ANS-45: Dec. 4 1-28 thru 1-38

Dec. 19

16 hours

SUMMARY

1. The lunar plane is inclined 5° with respect to the ecliptic plane.

2. The lunar plane rotates about an axis perpendicular to the ecliptic plane once every 18 1/2 years.

3. This rotation of the lunar plane causes the inclination of the lunar plane with respect to the equatorial plane to vary between $18\ 1/2^{\circ}$ and $28\ 1/2^{\circ}$ during the 18 1/2 year cycle. It also causes the ascending node of the lunar orbit to move alternately one hour to the east and one hour to the west of the vernal equinox.

4. The path of the Moon on a star chart is similar to that of the Sun. However, instead of crossing the star chart once a year, the Moon crosses it once every 27 1/3 days. Its maximum north and south declinations and the location of its nodes vary according to the rotation of the lunar plane.

5. The Moon's phase can be determined from its position on a star chart. It is new when its right ascension equals that of the sun and full when it is 12 hours right ascension away from the Sun.

6. Between two successive new or full Moons, the Moon will pass through approximately 26 hours of right ascension.

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